MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

MAIN OFFICE

Penton Building, Cleveland 13, Ohio

BRANCH OFFICES

New York 17 .... 16 East 43rd St.
Chicago 11 .... 520 North Michigan Ave.
Pittsburgh 19 .... 2806 Koppers Building
Detroit 2 .... 6560 Cass Ave.
Washington 4 .. 1123 National Press Bldg.
Los Angeles 4 130 N. New Hampshire Ave.
London, S.W.1 2 Caxton St., Westminster

Published by The Penton Publishing Co. E. L. Shaner, Pres. and Treas.; G. O. Hays, Vice Pres. and Gen. Mgr.; R. C. Jaenke, Vice Pres.; F. G. Steinebach, Vice Pres. and Secy.; E. L. Werner, Asst. Treas. Published on the seventh of each month.

This Month's Cover: Lamp filament winding machine, designed by Barth Stamping & Machine Works, coils an 0.0005-inch diameter tungsten wire around an 0.0025-inch steel core which is subsequently dissolved in acid to give a precision filament.

CONTENTS

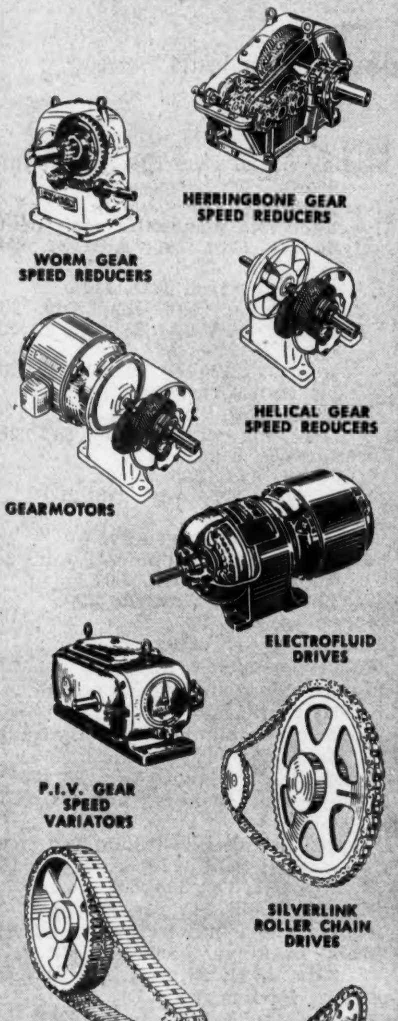
June, 1948   Vol. 20, No. 6

Itemized Index

Classified for convenience when studying specific design problems

MACHINE DESIGN is indexed in Industrial Arts Index and Engineering Index Service, both available in libraries generally

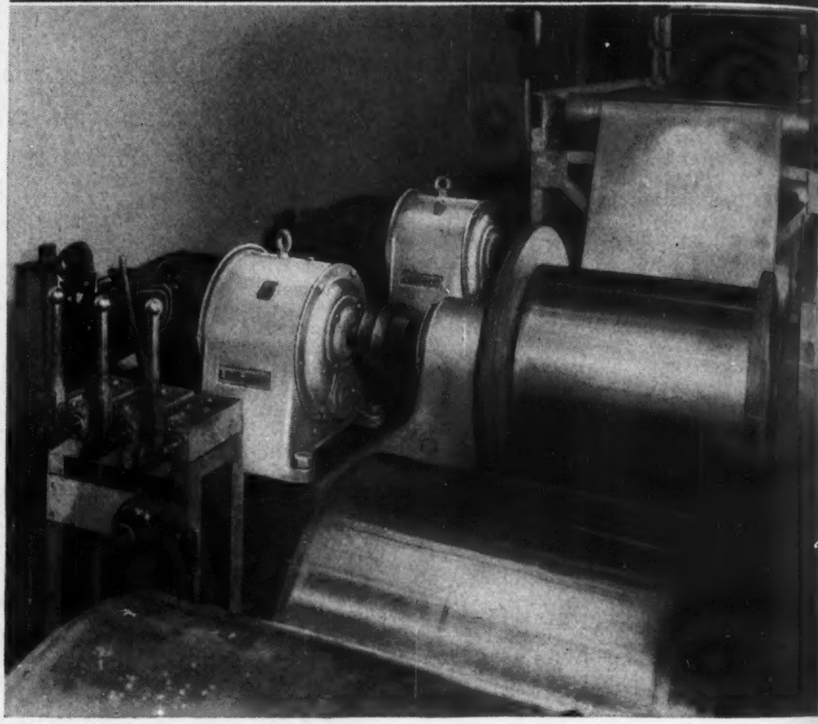
OTHER TYPES OF LINK-BELT POWER TRANSMISSION MACHINERY



If the Problem Involves

SPEED REDUCERS

Get Your Answer From **LINK-BELT!**



Because Link-Belt manufactures four types of speed reducers, you are sure to obtain the type and size which will serve you most satisfactorily when you come to Link-Belt.

In the view above an interesting problem is solved with Link-Belt helical gear speed reducers, coupled with D.C. generators connected to coil holders in a strip steel plant. The generators provide back-drag to supply proper tension on strip or act as motors when feeding the end of a new coil up to welding position.

Link-Belt speed reducers and gearmotors combine efficiently with any of the various Link-Belt drives to provide efficient, compact and durable power transmission at the correct speed.

Call on Link-Belt for aid and counsel on any mechanical power transmission problem.

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8.
Offices, Factory Branch Stores and Distributors in Principal Cities.

10,977-C

LINK-BELT

THE SYMBOL OF QUALITY LB LINK-BELT

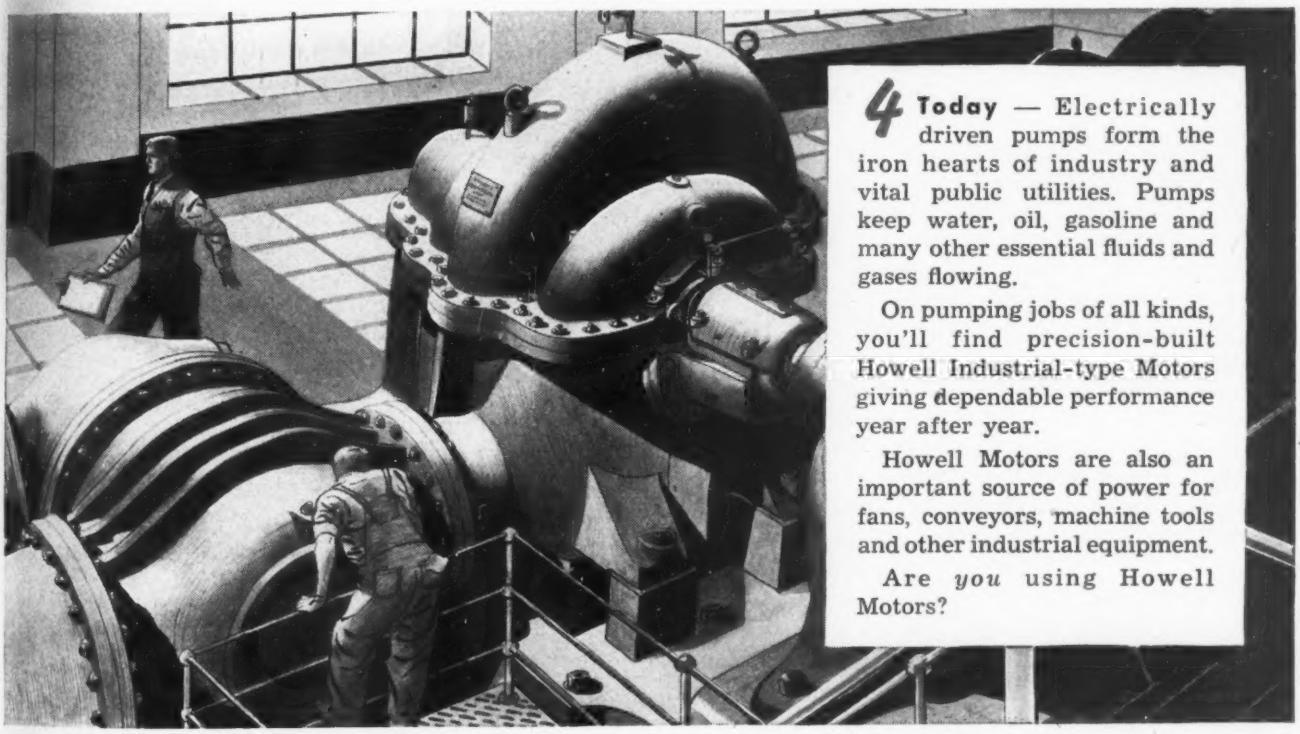
Power Transmission Machinery

1 **1643**—Torricelli, Italian physicist, hastened the development of modern hydraulic pumps when he found water could be raised in a tube by air pressure.

2 **1840**—Steam pump engines were helping to keep water out of mines. But low-cost electricity which put the *big* push behind pumping was still to come.

3 **1915**—Howell "Red Band" Electric Motors were introduced. Soon, these rugged, industrial-type motors gained wide recognition in this and other industries.

PUMPS . . . IRON HEARTS OF INDUSTRY!



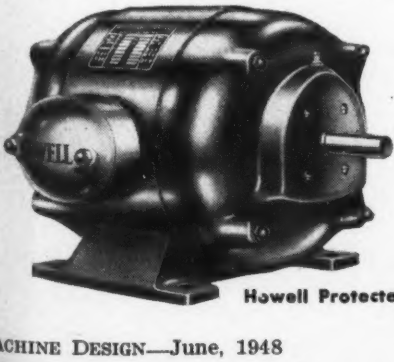
4 **Today** — Electrically driven pumps form the iron hearts of industry and vital public utilities. Pumps keep water, oil, gasoline and many other essential fluids and gases flowing.

On pumping jobs of all kinds, you'll find precision-built Howell Industrial-type Motors giving dependable performance year after year.

Howell Motors are also an important source of power for fans, conveyors, machine tools and other industrial equipment.

Are *you* using Howell Motors?

Here's another precision-built Howell Motor . . . industrial type with copper or bronze bar rotors . . . specially insulated . . . statically and dynamically balanced.



Howell Protected Type Motors

HOWELL MOTORS

HOWELL ELECTRIC MOTORS CO., HOWELL, MICH.

Manufacturers of Quality Industrial Type Motors Since 1915

Topics

SUPER-SPEED X-ray motion picture process, known as high-speed cineradiography, can analyze the internal structure of rapidly moving objects. Developed at the Westinghouse Lamp Research Laboratories the method utilizes 150,000-volt X-ray exposures of 100 millionths of a second and a shutterless camera with a speed of 100 frames a second. With the development of more powerful X-ray tubes it may be possible to inspect externally the internal action of airplane and automobile engines.

TEXTILE INDUSTRY now employs 38 per cent of all the nation's industrial workers, according to the N. Y. Journal of Commerce.

ELECTROPLATING of magnesium alloys by standard techniques is now possible through the use of a new process for depositing a thin film of zinc on the metal. Developed by the Dow Chemical Co., the process involves treatment in a bath which deposits an extremely thin film of zinc on the surface of the alloy. Chromium, silver, gold, copper, brass, cadmium, zinc, etc., platings have excellent adhesive properties.

DESIGNED to move passengers more comfortably and quickly, elevators in Jordan Marsh's Boston department store will have private cockpits attached to the sides of the cabs for the operators and automatic wire recordings to announce the floors.

INVESTMENT-CAST milling cutters made from remelted high-speed steel scrap have shown excellent performance in tests at Watervliet Arsenal. Since the cast structure of high-speed steel is ordinarily broken up by hot work, heat treatment is used for the precision-cast cutters in an attempt to accomplish the same result.

CHROMATED PROTEIN coating is a convenient, inexpensive method of protecting zinc, iron, brass, and aluminum during outdoor storage in mildly corrosive atmospheres. The protective value of such films, developed at the National Bureau of Standards, is somewhat better than that afforded by chemical surface treatments and is much superior to that of corrosion - inhibited oils and waxes. Surfaces to be treated are dipped in casein, albumin or gelatin; the resultant film is then impregnated with chromate which hardens the coating and inhibits corrosion. Films are quickly removed with an alkaline solution such as 5 per cent sodium hydroxide.

DOMESTIC HEATING unit designed to burn either natural gas or fuel oil as well as a combination of both is the answer of the Midwest Research Institute to the nation's home-heating problems during severely cold weather. Efficiency of the unit is equal to existing ones designed for either fuel. Parts required in the gas cycle will also perform a service in the oil cycle, eliminating duplication of parts if separate burners were used.

PRODUCTION of rayon, nylon and other synthetic fibers totaled about 1,030,000,000 pounds last year and by the end of 1949 the capacity will be increased 26 per cent.

PERMENORM 5000-Z, a magnetic alloy which will make possible revolutionary changes in the rectification of electric power, has been reproduced for the first time in the United States at the Naval Ordnance Laboratory, White Oak. Maryland. The alloy, resulting from a fusion of nickel and iron under an intricate heat treating process, was first synthetized in 1943 in Germany. Also useful in the fabrication of magnetic amplifiers, the alloy may replace many of the complicated and delicate electronic tube amplifiers in guided missiles and fire control equipment.

NEW SYSTEM of photographic analysis developed by the Navy is capable of accurately magnifying time by some four million times. The system is called synchronized micro-time photography.

MACHINE DESIGN

What Recent Research Offers the Designer

By Norman C. Penfold
Chairman, Mechanical Engineering Research
Armour Research Foundation

PROGRESS in design engineering has always been closely related to and dependent upon the characteristics of materials, technical processes, scientific principles and production methods. In a sense these have constituted important tools of the design engineer. In these fields, both fundamental and applied research aid the design engineer in his task of utilizing materials more effectively to lower production costs and improve production techniques. In addition, he is helped to make rapid analytical selection of materials and to increase his knowledge of fundamental mechanics, energy exchanges and other technological tools.

It is difficult to draw a line of demarcation between fundamental and applied research, and a clear distinction is not necessary for the present purpose. Indeed, the distinction largely rests with the individual's concept of research, and fundamental or pure research eventually becomes applied research or design engineering, depending on circumstances. The

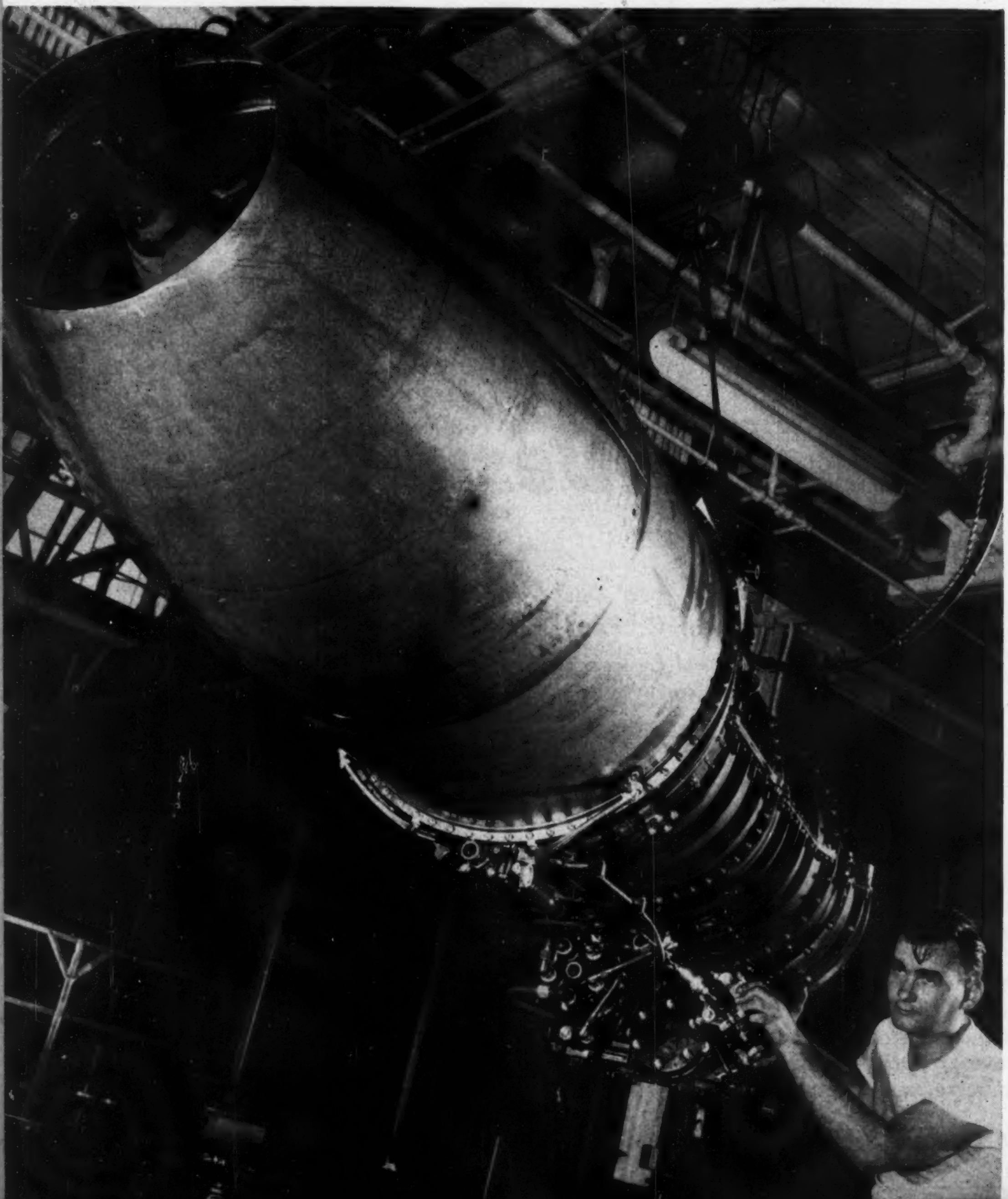
research, whether engaged in fundamental or applied research activities, is essentially a fact-finder. As such, he provides the scientific and technological world with facts, whether he is developing those facts for a specific purpose or purely in a spirit of inquiry. These facts expand our knowledge of present materials, principles and processes. In addition, they lead to the development of new materials, new methods and new processes—new tools for the design engineer.

One of the design engineer's most important functions is to select the best available materials for a purpose. Such selection requires that economic studies be made in which factors of material cost, material strength, fabrication cost and others are considered. Certain physical requirements such as high tensile strength, high resistance to impact, or low weight may limit the number of materials which might be used. Again, requirements such as corrosion resistance, weldability, appearance or thermal conductivity may further restrict selection.

If the designer had a virtually unlimited number of materials to choose from, and if these materials had a practically unlimited range of physical characteristics, the problem of selection would be simplified considerably. Assuming that the characteristics of the desired material were clearly defined, the selection would only involve the consulting of tabulated data. Unfortunately, the known materials fall far short of permitting such a choice. In fact, it sometimes seems that in spite of advances in recent years, we have only begun to realize the potentialities of materials and are still quite far away from being able to synthesize ones of specific qualities.

Development of the gas turbine depends more than anything else on the discovery of materials which will withstand high temperatures and high tensile stresses and at the same time be resistant to mechanical and thermal shock, corrosion and erosion. Many of us are familiar with the limitations placed on the designer of a gas turbine by the shortcomings of presently available materials. How different would the task of the designer be if he could establish op-

Photo, courtesy Westinghouse Electric Corp



"Development of the gas turbine depends more than anything else on the discovery of materials which will withstand high temperatures and high tensile stresses and at the same time be resistant to mechanical and thermal shock, corrosion and erosion"

Photo, courtesy Westinghouse Electric Corp.

"Fundamental research in electronics has provided vacuum tubes and associated electronic devices." Photo shows glass craftsman fabricating a complex custom-made electronic tube for use in research

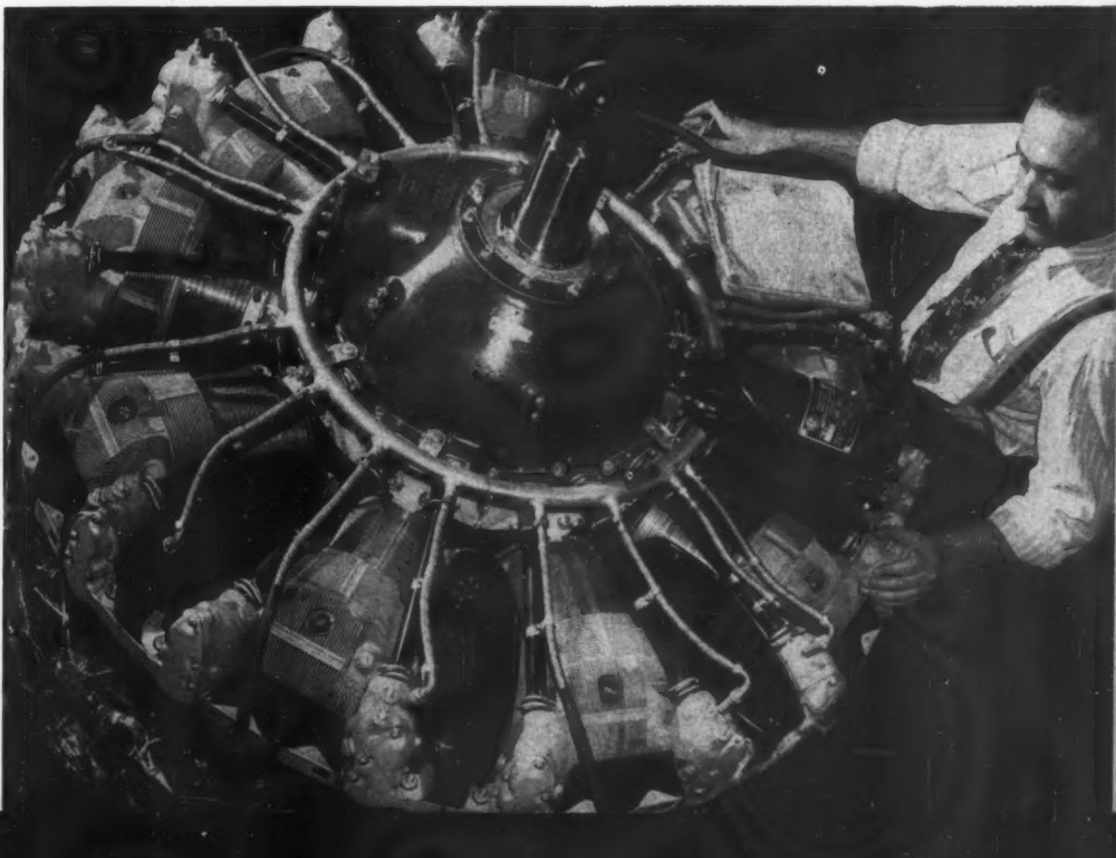
timum gas temperatures for the turbine, select the most suitable thermodynamic and aerodynamic conditions for highest efficiency, and then design the unit knowing that materials were available which would meet the requirements!

Unfortunately, such materials are not now available. The future certainly holds promise, however, and research will provide materials which more closely approach the ideal as time goes on. Actually there are large gaps in our knowledge of present materials which need filling if the designer is to utilize these materials most effectively. The design engineer is often forced to "overdesign" in order that machine failures be prevented, just because specific data is lacking which will permit him to produce the most economical design without approaching too closely the failure point. When overdesign is impractical or not permissible, the experimental engineer may have to resort to cut and try methods to satisfy the circumstances; this, because of gaps in our knowledge which fundamental research must logically fill.

Increased use of rubber-like materials and plastics has emphasized the lack of knowledge of good design principles. Since these materials do not obey the familiar laws applicable to metals such as steel, new concepts of properties which constitute good design are needed. The designer must be closer to the fundamental research in progress in these fields and must participate in efforts of co-ordination so that resulting data will not only be more quickly available to him but will be more valuable because they may be more effectively applied. Those engaged in both fundamental and applied research may give considerable aid to the design engineer by providing him with means for evaluating and interpreting data.

Many specific examples of new processes, materials or design tools may be cited which have resulted from fundamental research. Highly theoretical work, fol-

Photo, courtesy Wright Aeronautical Corp.



"Highly theoretical work . . . has enabled the designer to cope more rationally with problems in cooling-fin design." Photo shows 9-cylinder aircraft engine having forged-head cylinders with W-type cooling fins

"Extensive research in metallurgy, the corrosion of single crystals of metal, in lubricating-oil corrosion inhibitors and in other factors affecting corrosion and bearing load-carrying capacity have substantially increased the available information on bearings and their application." Here an engineer takes a photomicrograph of a Kingsbury-type thrust bearing surface

Photo, courtesy Westinghouse Electric Corp.

lowed by experimental investigation, on heat transfer rates by conduction, convection and radiation for various structural configurations, has enabled the designer to cope more rationally with problems in cooling-fin design. Such work, when coupled with data made available by aerodynamic researches, permits, for example, better design of heat exchangers and engine cylinder barrels. Fundamental research in electronics has provided vacuum tubes and associated electronic devices which the designer may apply for control, instrumentation and other uses.

Extremely small vacuum tubes, "printed" electronic circuits, high-frequency heating and optical-electronic developments are enjoying increased application by the machine designer. The study of Newton's rings was once a laboratory curiosity; this same principle is now widely employed as an interference phenomena for optical flats used in precision measurement work in gage laboratories. Fundamental research on X-rays, and more particularly that on X-rays of very high penetration, now permits the inspection of thick sections of metal to determine the presence of flaws. The result is elimination of faulty materials through nondestructive inspection of their interiors. Thus, the structure may be designed with a lower factor of safety. Shot-peening of metals to improve physical properties and fatigue life is a further example of the contribution of fundamental research and experimental analysis to the production of superior materials.

An outstanding example of what the designer may receive from the fundamental research laboratories is afforded by a consideration of the development and application of silicones. Originally conceived in the minds of chemists and later synthesized in the laboratory, silicones of various compositions are now used for special lubricating purposes, as gasket materials, as a mold release, as anti-foam agents for mineral lubricating oils, as hydraulic fluid for vibration damping, as resin for high-temperature electrical insulation, as protective coating, as high-temperature grease and many others. The designer has not yet been able to find uses for some of the silicone compounds and others will certainly be forthcoming having quite unusual properties.

Bearings Stronger, Longer Lived

Bearing materials of improved load-carrying capacity and resistance to corrosion have permitted the designer to reduce the size and increase the life of many mechanical products. In internal-combustion engines the crankshaft may be shortened with resultant improvement in rigidity; reciprocating weights may be reduced by the use of the smaller bearings. Extensive research in metallurgy, the corrosion of single crystals of metal, in lubricating-oil corrosion inhibitors and in other factors affecting corrosion and bearing load-carrying capacity have substantially increased the available information on bearings and their application. Much work remains to be done on very high-speed bearings and on the hydrodynamic

considerations of oil flow in a bearing, point of entry of oil to the bearing, size and location of grooves and lubricant characteristics as related to bearing selection and design.

Hydraulic accumulators of the bag-separator type were widely employed in hydraulic systems in military aircraft during the last war. These were the direct outcome of earlier researches on gas absorptivity of hydraulic oils, resistance of rubber-like materials to oils, stress analysis of thin-shell cylinders and spheres, and many related studies. Such hydraulic systems were designed for light weight, relatively low cost and compact functions of unique character.

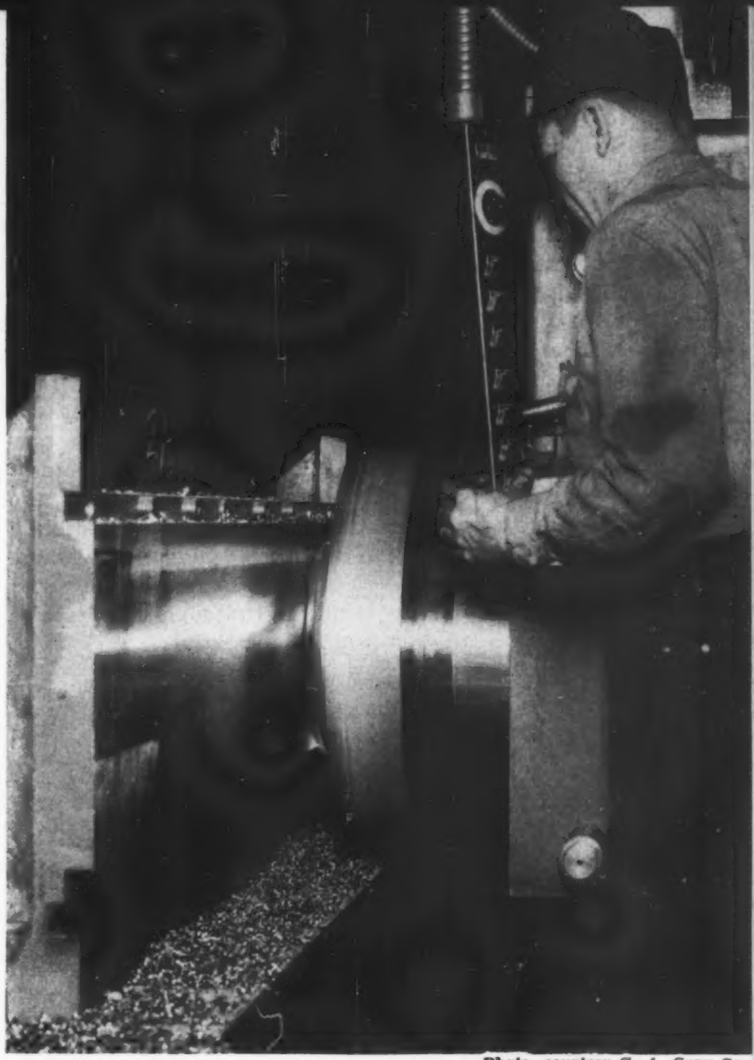
Bonding of dissimilar metals has provided stainless and copper-clad steels for desired combinations of strength, corrosion resistance, appearance, ease of fabrication, and resistance to fatigue. The many methods by which this bonding may be accomplished and the large variety of metals which may be treated in this manner provide the designer with a good many more possibilities when he is considering the materials which he might use most effectively for a particular application. Research in ceramics will provide the designer with ceramic coatings particularly for cast iron and steel which will further enhance material selection possibilities.

Powder Metallurgy Holds High Promise

Powder-metallurgy techniques furnish further evidence of the role which fundamental research may play in the function and activities of the machine designer. As well as providing a low-cost, high-production fabrication process, these techniques also furnish materials of unusual and useful properties. Now used for self-lubricating bearings, metal cutting tools, seals, filters and many other purposes, continued research will provide additional metals formed by this process which have more specific or superior properties as electrical contacts, abrasion-resistant alloys, high-temperature bearing materials with increased load-carrying capacities, corrosion-resistant coatings and many others.

Fundamental research in extremely high pressures is beginning to provide the data which are necessary for the development of materials and lubricants for bearings, gearing and other applications. Gear failures are almost always the result of fatigue caused by metal surface deformation and the designer at the present time is able to utilize only a small fraction of the inherent strength of the metal in the design of gears. Extreme-pressure lubricants, particularly those of the hypoid variety, have demonstrated their ability to permit operation of gears at higher loads before failure is experienced. The designer has many incentives to reduce the size and weight of gearing and this usually can be done only by increased speed and gear tooth pressures. Fundamental research on the behavior of lubricants and metals under high pressures, coupled with functional tests on gearing and gear lubricants, will enable the designer of gearing to meet demands for small, more highly-loaded gear sets.

Precision casting techniques, long employed by the dental and medical professions, are now in wide usage for the fabrication of shapes hitherto impossible or extremely expensive. Rubber molding and rubber injection processes have further increased the designer's choice of materials and suitable manufacturing processes.



Photo, courtesy G. A. Gray Co.

"The designer looks to the fundamental research laboratories to provide him with improved methods of fabrication or new techniques." Flywheel-type carbide cutter is shown removing 50 cubic inches of metal per minute from surface of 0.40-carbon steel rack forging

The benefits of atomic research are now beginning to find industrial application in which the machine designer is playing and will play an increasingly important part. These benefits now are largely usable only by research laboratories and have been most quickly applicable to medical research. However, the metallurgist, geologist, power engineer and instrument designer may avail themselves of many of these benefits.

Since the designer must consider fabrication techniques applicable to various materials he may choose as having the desired characteristics, he looks to the fundamental research laboratories to provide him with improved methods of fabrication or new techniques. Considering again the designer of a gas turbine, how often after selecting promising materials does he find serious fabrication difficulties! Perhaps

the material cannot be welded satisfactorily; or perhaps the complicated and time-consuming heat treatment to relieve the welding stresses is so expensive that the material cannot be used. How convenient it would be if research could provide, at little cost, materials to any specification the designer chose!

Many different processes are usually applicable to fabrication of the same material. Generally, the designer has the benefit of previous use and the field of application has been narrowed somewhat by the long experience of others. The average designer cannot be acquainted with all of the many processes applicable to all materials, but he usually has the opportunity to specialize to some extent in certain classes of materials, or the type of industry in which he is employed may dictate the family of materials to be used. In any event, a thorough and precise organization of data would be helpful.

Way Cleared to More Practical Analysis

Research has provided the design engineer with experimental analysis techniques for use where mathematical analysis is too complicated. A good example of this is the increasingly important use of a model analysis which calls for the construction of a scale model of the machine in plastic having a modulus much lower than that of the machine material. Deflection of the model under stress bears a definite relationship to that of the finished machine, depending on the modulus of the model material and the scale of the model. Such a technique permits the designer to construct models, measure deflections under various loads, then make most effective use of materials and provide adequate safety factors without "overdesigning".

Electrical gaging methods for determination of pressure, vibration, movement and strain are the result of combined efforts of researchers and design engineers and provide ingenious tools for better design practices. Oscillographic instruments are now commonplace and are a valuable adjunct to the growing list of technological aids. Scientific instruments which have been conceived and developed in research laboratories are being redesigned for more general use. This redesign is aimed at reduction in cost and simplification of operation so that operation may be done by technician-quality personnel. Automatic operation of such instruments further improves their usefulness and further removes them from the sole province of the fundamental researcher. Spectroscopic instruments, photometers, X-ray and electron diffraction apparatus are among the instruments which will become increasingly more useful in the work of the designer.

New Tools Reveal Dynamic Stresses

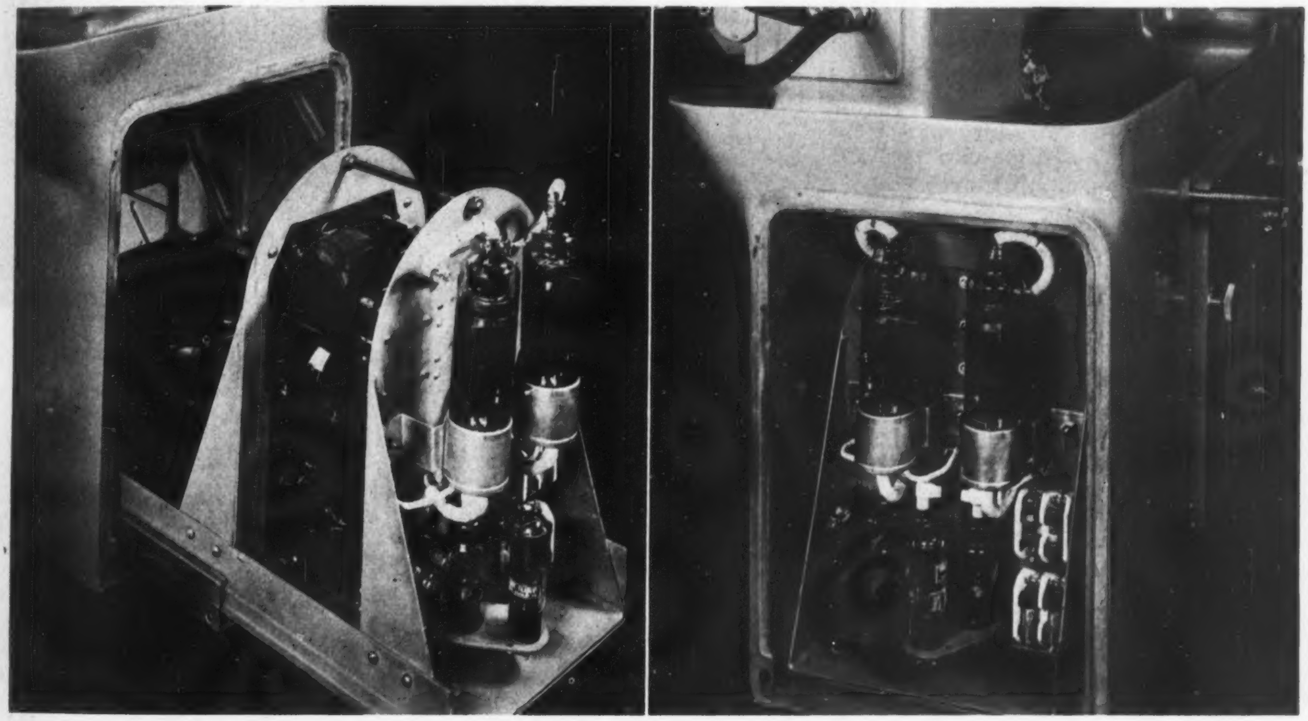
Accurate stress determination is one of the most difficult tasks the design engineer has. New methods of experimental stress analysis will permit more accurate results than the combination of safety factors and empirical formulas which the designer must sometimes rely upon. Photoelasticity, stress coat, electric strain gages and extensometers are among the presently available aids to the designer in this connection. The designer has also found, or will find, that increasing importance will be given to stress determination under dynamic rather than static conditions, since the importance of dynamic considerations is frequently demonstrated where failure of parts or structures is experienced. Motion analysis by high-speed photography, the use of stroboscopic instruments and the use of the ocillograph in combination with electric strain gages will permit the designer to study and determine dynamic stresses more accurately under various operating conditions. Critical examination of parts or structures which have failed provides additional design information, and many techniques are available for this purpose. Radiography and supersonic echoes are among the newer techniques in this field.

We are confident that research, if properly directed, can produce wealth, an expanding market for the useful things created by the designer and a fuller sphere of activity for the designer. Research is undoubtedly among the most potent constructive forces we possess; but it can be made destructive also. We, as engineers, must give more thought and energy to keeping fundamental research vital and applied research constructive if we are to enjoy the benefits which result from research.

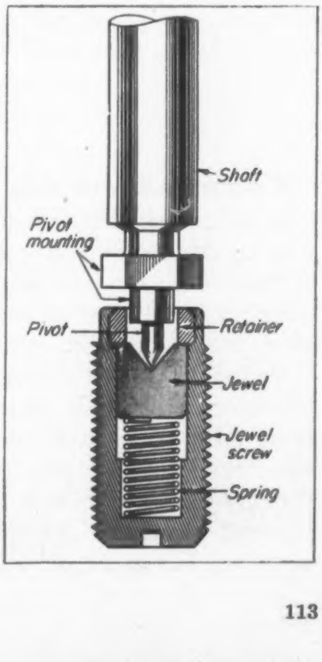
"Use of stroboscopic instruments and the use of the oscillograph in combination with electric strain gages will permit the designer to study and determine dynamic stresses more accurately." Photo shows balancing of rotors on electromagnetic machine. By means of stroboscope, operator sees spot on revolving rotor that is out of balance, and reads amount directly on meter

Photo, courtesy Westinghouse Electric Corp.

Scanning THE FIELD for Ideas

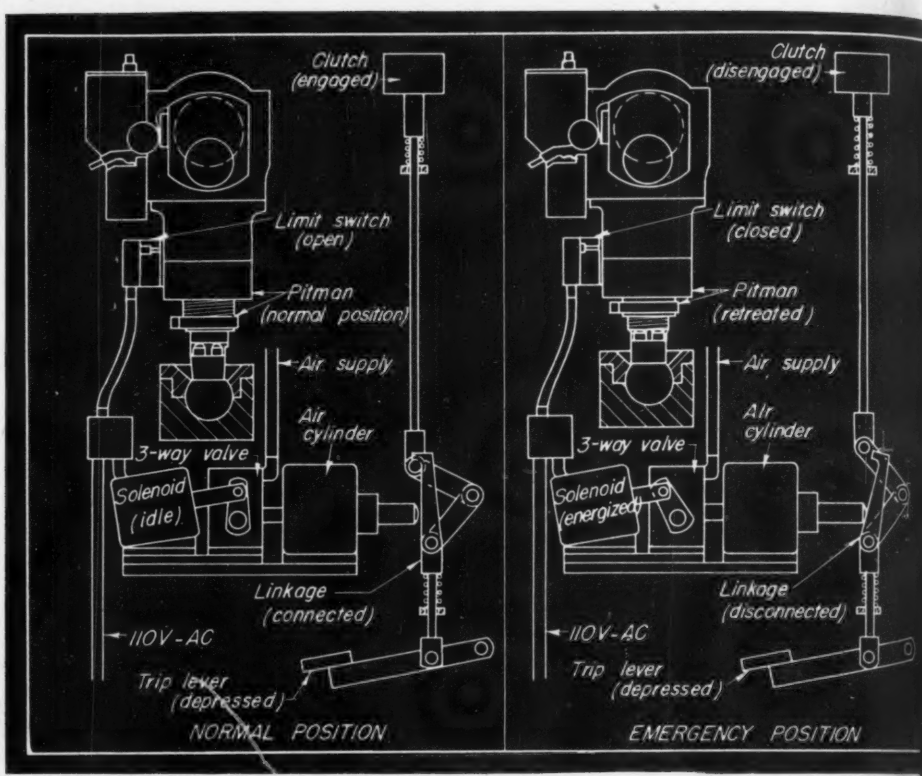


Accessible, yet neatly tucked away when not being serviced, the electronic control equipment shown above is mounted in the base of a Monarch lathe. The chassis slides out on a roller bearing telescoping suspension much like an office filing cabinet. This makes the whole unit readily accessible to the service man, a feature which the customer appreciates. The control provides direct-current, adjustable-voltage control for the spindle motor. Its circuit employs 16-ampere xenon-filled tubes together with control tubes, resistors, capacitors, etc. In size the control is considerably smaller than conventional electronic units.

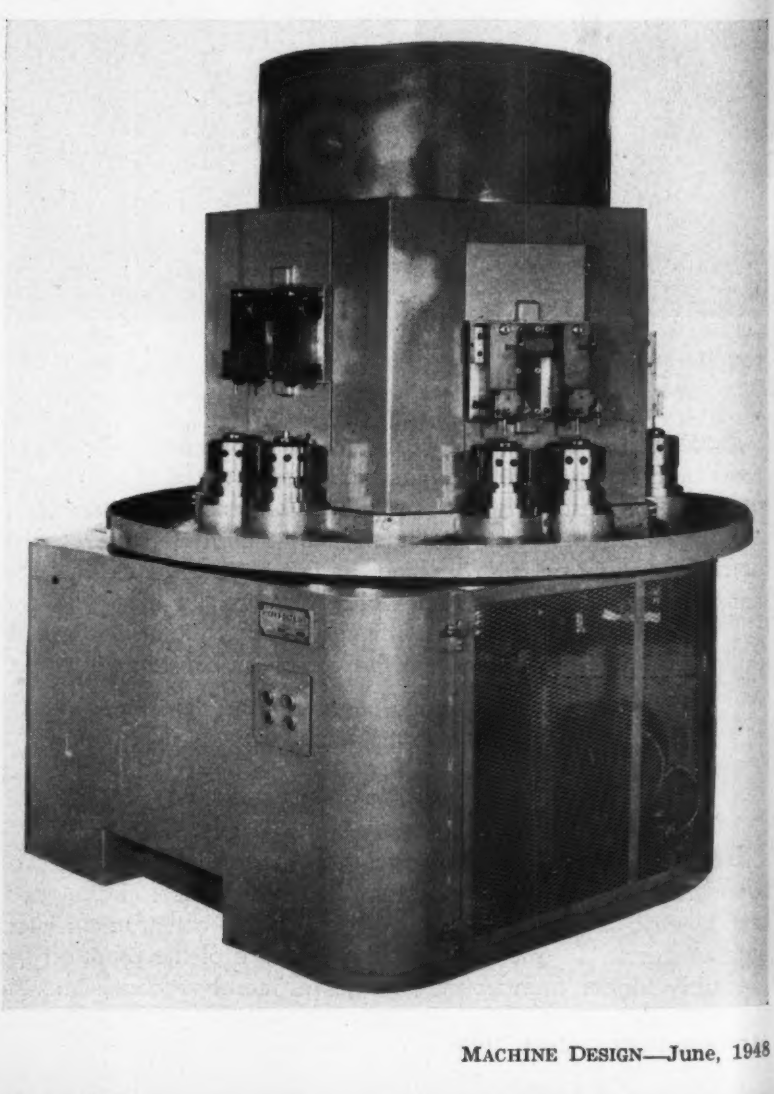


Bearing with spring-mounted jewel as shown at right protects its pivot even under conditions of abnormal shock or abuse. Developed by the General Electric Co. for instruments, the bearing construction permits hard use without harm. If, due to shock, the pressure of the pivot on the jewel is appreciably higher than normal, the jewel merely recedes into the screw. Be-

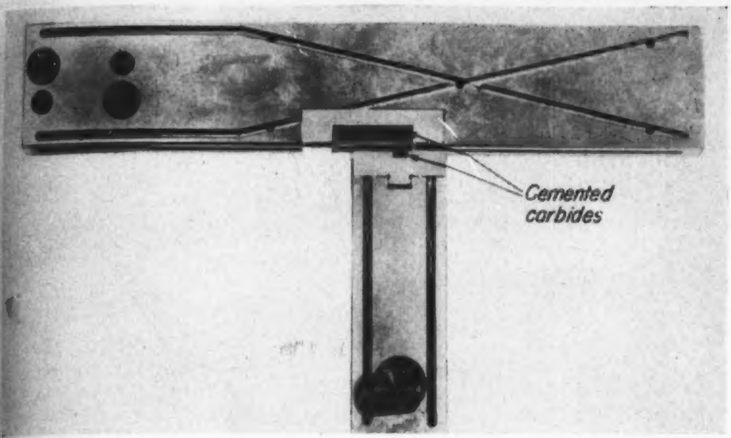
fore the jewel hits bottom, the shoulder on the end of the shaft strikes the top of the jewel screw and takes the shock, thus protecting the bearing against possible damage.



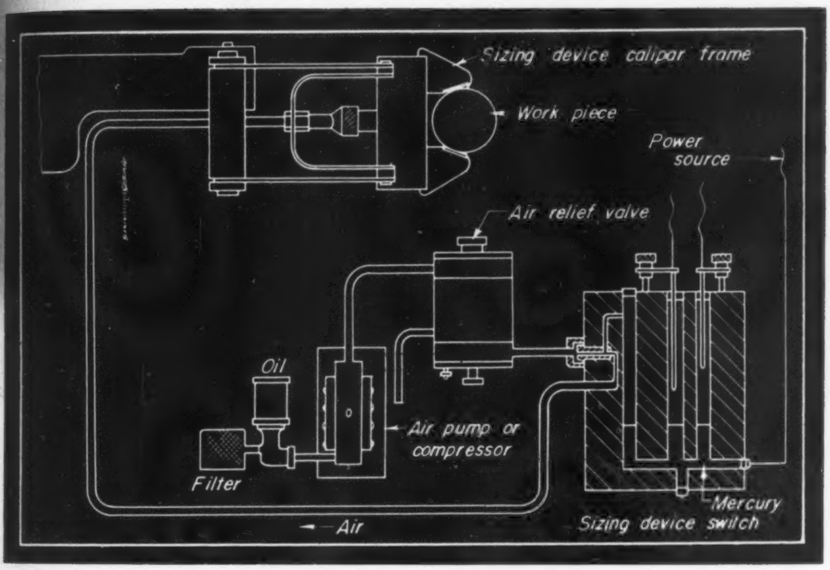
Hydraulic pitman illustrated in the sketches at right has an automatic cutout in case of overload. As long as the pitman is in normal working position, the limit switch remains open. In event the dies become jammed, by the introduction of two or more pieces into a given work station, the pitman and ram close the limit switch. The closing of the switch energizes a solenoid and opens a 3-way valve, which in turn energizes a power air cylinder. This cylinder trips a linkage mechanism which automatically disengages the press clutch and brings the press to a definite stop before the next work cycle of the press crank. This arrangement, designed by the Dayton Rogers Manufacturing Co., in no way interferes with the intermittent operation of the press. However, when the press is to be run continually, and the press tripping lever is depressed, it assures continuous operation.



Cemented carbide inserts provide wear resistance on the cams utilized on the five-station ten-spindle precision boring machine shown at right, insuring continuity of accuracy and long life. Designed by Hoern and Dilts Inc., the machine also uses solid Carboloy cemented carbide bars to bore parts of greater length-to-diameter ratios with greater accuracy. Rigidity of the carbide is 2.8 times that of steel, reducing both deflection and wind-up. For example, valve guides of



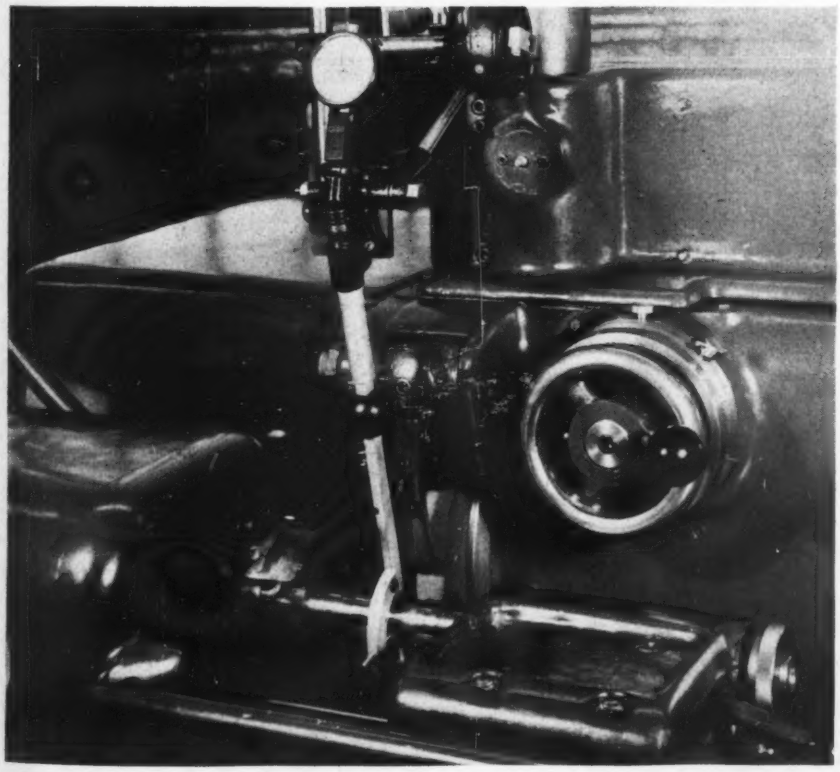
6:1 length-to-diameter ratio are being bored to a precision of 0.001-inch on diameter and 0.0002-inch for alignment and concentricity. Operation of the tool slide is through a master cam mounted on the machine column. Intermediate cams control infeed of the tools. The tool slides, instead of being cast iron, are tool steel. Inserts as used in the cams are illustrated at left.

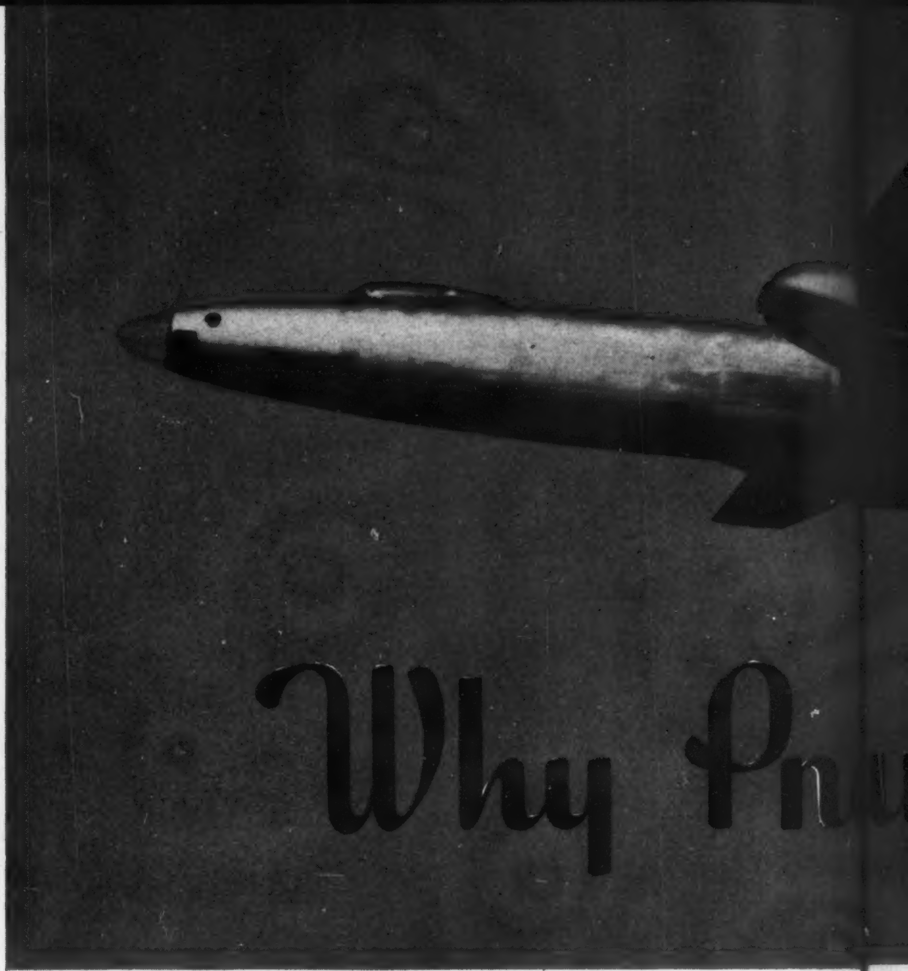


Air mercury sizing control gages the workpiece while the grinder illustrated at left in in operation. Upon approaching size the control slows down the feed of the grinding wheel. When size is reached the wheel retracts automatically.

As shown in the schematic sketch at left of the device, which has been developed by Landis Tool Co., air pressure at approximately 2 psi from a compressor goes direct into the air relief valve which is a combination filter and pressure regulator. From this valve the air passes through a mercury switch to an air jet mounted in a caliper frame. This frame is equipped with two Carboloy tipped shoes that rest lightly against the work.

While grinding proceeds, the sizing head moves slightly forward, decreasing the gap between the work and nozzle. This movement causes pressure to build up in the air line and the mercury to rise in the switch. Just before the work reaches final size the mercury rises to the lower contact in the switch, energizing the control circuit for slow feed. As the mercury rises higher it touches the second contact, causing the grinding wheel to move away from the work. For various diameters of work the caliper frame jaws and the position of the jet are adjustable. The contacts in the mercury switch may also be adjusted to make contact at the desired pressure for maximum sensitivity of the control unit.





PERHAPS the question most often asked about the high-speed bomber XB-46 shown in *Fig.* 1 is, "Why did you choose pneumatics rather than an electric or hydraulic system to operate the landing gear, bomb-bay doors and brakes?" The best way to answer this question is to present factual data showing that pneumatics proved the best choice for intermittent, high-speed, heavy-load, operation of various units on the airplane.

First, the primary advantages of a pneumatic system—advantages that make it preferable to any other source of power—might be outlined as follows:

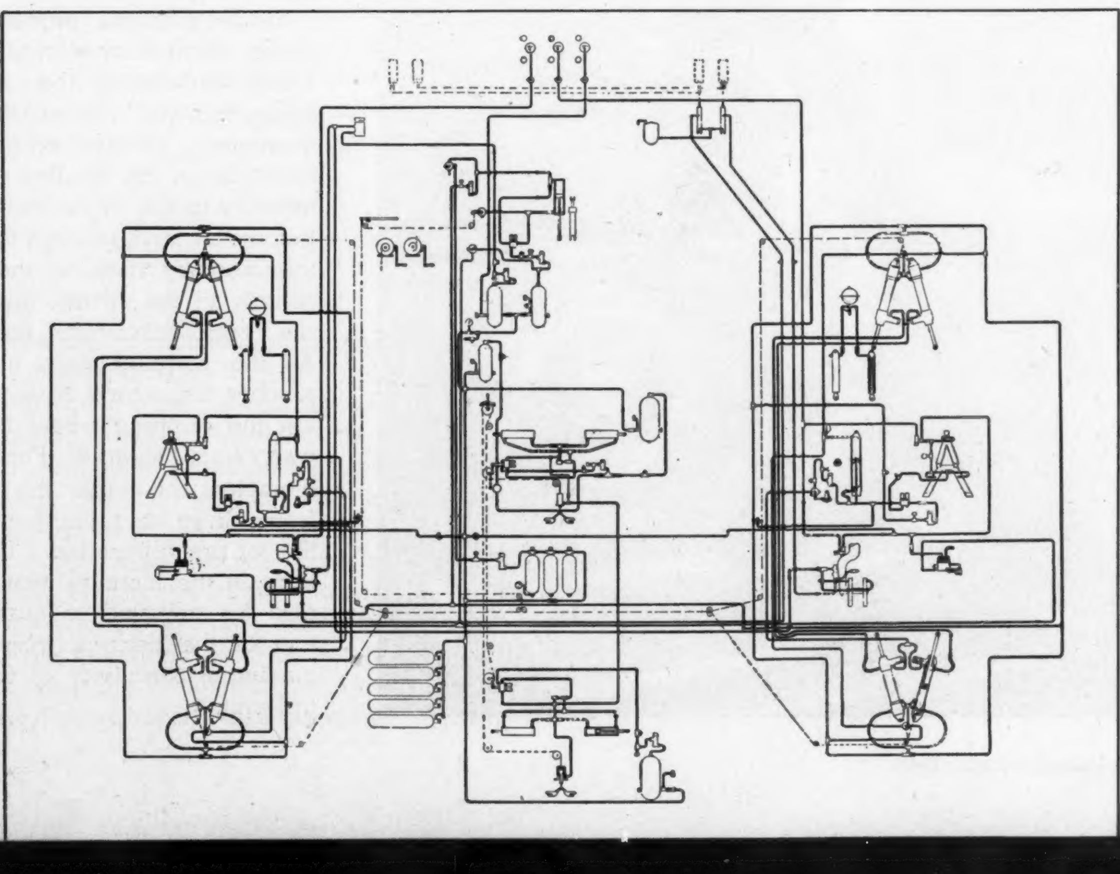
1. For the horsepower delivered, a pneumatic system weighs less than any other system developed to date

By Harvey F. Gerwig and **Joseph H. Famme**

Assistant Group Engineer *Project Engineer*

Consolidated-Vultee Aircraft Corp.

San Diego, Calif.



Part I—System and Equipment

DESIGN incorporating the use of pneumatics at pressures beyond those commonly employed has rarely been attempted. In the interest of furthering development of high-pressure pneumatics into the realm of 1500 to 2000 psi pressures, the authors have prepared this interesting article. It is hoped that the experiment discussed will open the way to a new and broader field of drive and control possibilities

2. It requires the least amount of power from the engine in flight, because its potential energy can be stored by ground charging. The result is increased safety at takeoff (when all power may be needed to clear obstacles) and substantial fuel saving
3. Air, the medium of potential energy, is at all times available at no initial cost
4. Unlike an electrical or hydraulic system, a pneumatic system is completely free of fire hazards
5. It is the cleanest system of all. Leaks—easily detected by the sound of escaping air—create no mess whatsoever
6. A pneumatic system is ideal for operation during the extremes of winter and summer because the viscosity of air is very low, even at −650 F, so

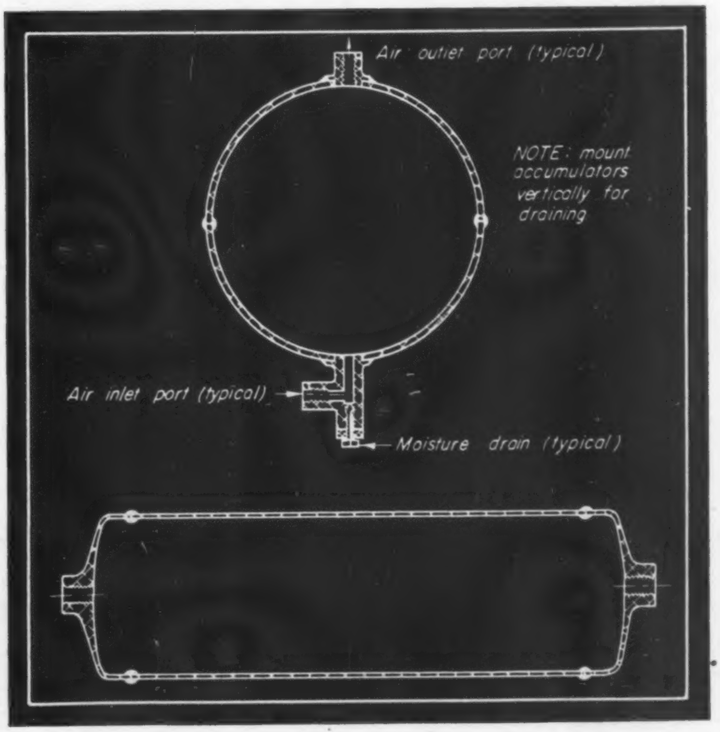


Fig. 1—Top—Consolidated-Vultee high-speed jet bomber XB-46, landing gear, fuselage bomb-bay and brake systems of which are pneumatically operated. Storage pressure is 1500 psi

Fig. 2—Left—Schematic diagram of the XB-46 high-pressure pneumatic system

Fig. 3—Right—Typical spherical and cylindrical pneumatic accumulator bottles

lines can be small. In comparable 3000-psi hydraulic systems the line sizes reach 1¼ inches in overall diameter, whereas the largest line in the pneumatic system is ⅜-inch in overall diameter. Air, unlike viscid fluids, does not congeal. Freezing of moisture deposited from the air into the accumulators, originally considered a problem, has proved to be of no consequence. Air delivered from a ground-charging compressor is practically dry. An engine-driven compressor operating under the most humid conditions and delivering five cubic feet per minute of free air at 1500 psi discharge pressure, would deliver only a gallon of moisture in eight hours of continuous running

With the compressor only operating an average of 12 minutes per flight, this amounts to only 5.77 cubic inches—small indeed when compared to the system volume of 7000 cubic inches. At 37,000 feet altitude or −67 F temperature, the rate of actuation of bomb doors, camera doors or flare chute doors will be the same as on the ground at standard conditions. This fact is of great importance in checking out operations during preflight inspections. In the case of hydraulics this would not be true. Pressure loss from line friction is insignificant at any of the required operating temperature ranges and serious shock waves due to surge pressures do not occur, air being a compressive medium

7. Air, because of its compressibility makes an ideal cushion for arresting the motion of an actuating cylinder piston which is traveling at high velocity. This cushioning or snubbing can be easily accomplished by introducing air pressure to the

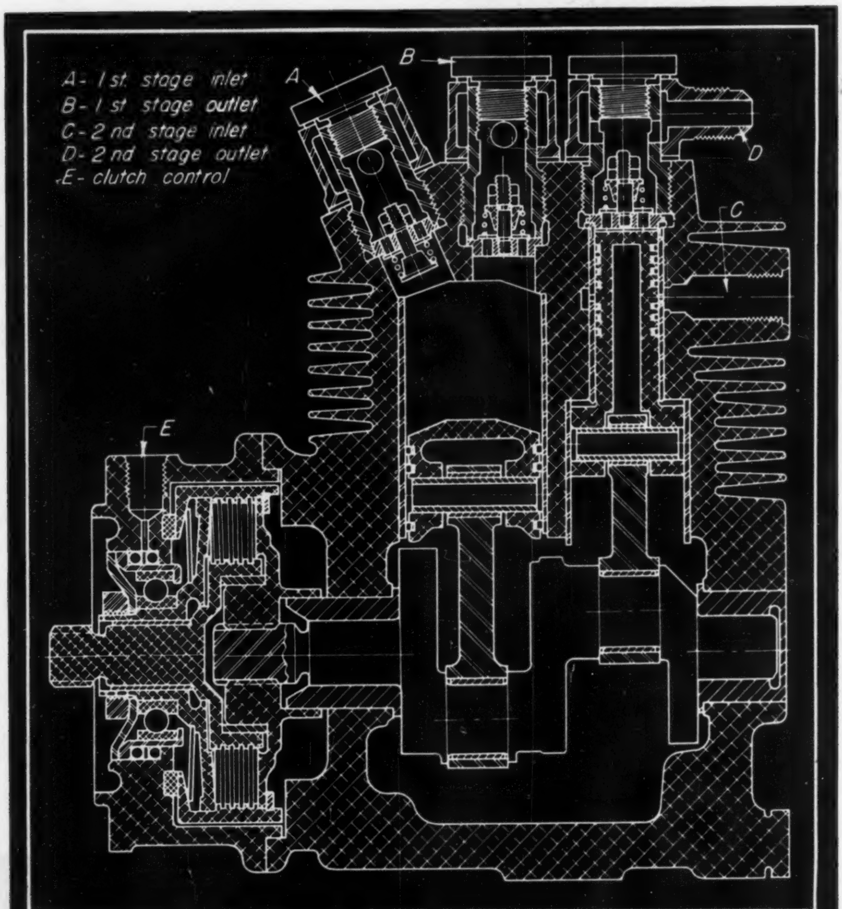
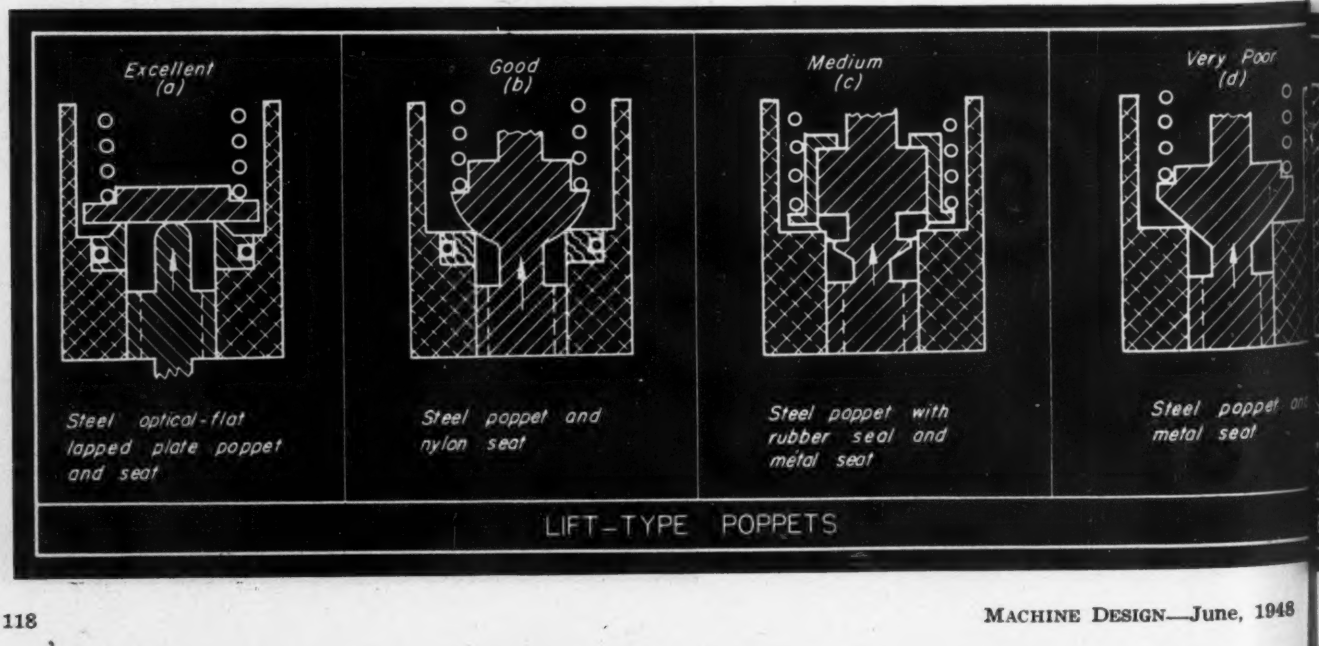


Fig. 4 — Left — Automatic two-stage Westinghouse compressor for the system weighs but 15 pounds

Fig. 5—Below—Various types of pneumatic valve seat and poppet designs



opposite side of the piston from the side producing the actuating force. Adiabatically compressed at the end of the stroke, this pressure stops the piston with no resulting impact

8. Sonic velocities can be achieved when the air storage pressure is twice that of the operating pressure. This permits the design of units for split-second operation if such is the requirement. Regardless of how many times the ratio of air storage pressure to operating pressure is increased, the mass flow will not change. Because of this fact the most practical operating pressures range from one-fourth to one-third storage pressure.

PNEUMATIC SYSTEM AND EQUIPMENT: The XB-46 pneumatic system which is quite simple, as shown by the schematic diagram *Fig.* 2, is composed of the following major pieces of equipment.

Accumulators or Storage Bottles: These units store air pressure at 1500 psi and provide sufficient potential energy for two cycles of operation without recharging. The units are ground charged before takeoff by a high-capacity service compressor and are maintained in flight by a low-capacity, engine-driven compressor or its equivalent. Normally one accumulator, *Fig.* 3, is located at each unit.

Compressors: Usually of the two-stage piston type, compressors can be driven by any one of three methods: (a) Direct engine drive by means of standard gear reduction engine pad, (b) by an expansion turbine which receives energy from the surplus air bleed of the engine compressor, or (c) by electric motor, but this generally is uneconomical because of inefficiencies. One of the most advantageous installations of an engine-driven compressor is in combination with a jet engine of 4000 pounds thrust, which provides a supercharge of 34 psi from the last stage of its compressor and thereby reduces the charging time of the pneumatic compressor both at sea level and at altitudes. The most practical compressor developed so far is an engine-driven, two-stage piston type that delivers five cubic feet of free air per minute at a discharge pressure of 1500 psi. This small, compact unit, *Fig.* 4, weighs only 15 pounds.

Pressure Regulators: These units which reduce the

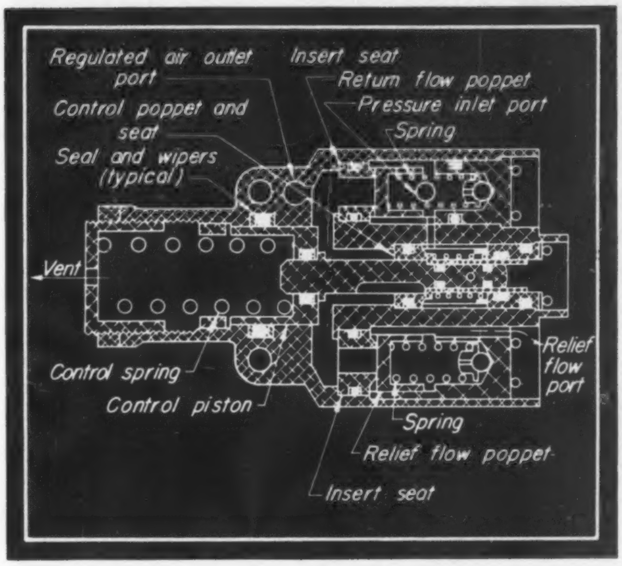


Fig. 6 — Above — Weston adjustable pneumatic pressure regulator using optically flat plate poppet

Fig. 7—Below—Weston adjustable pneumatic relief valve

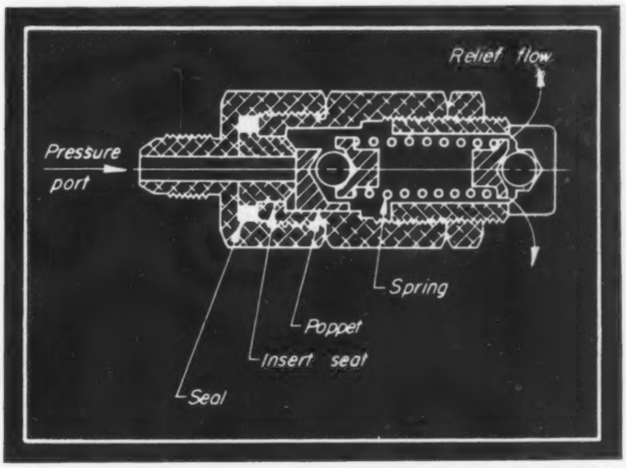
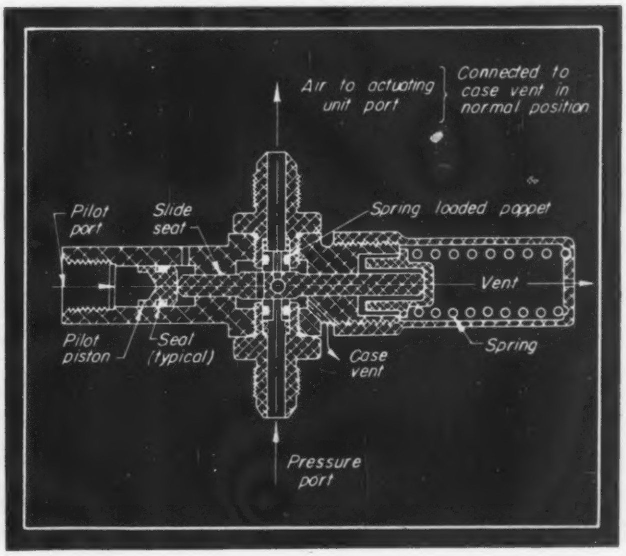


Fig. 8—Below—Saval pneumatic pilot-operated selector valve. Design is typical of solenoid valve also



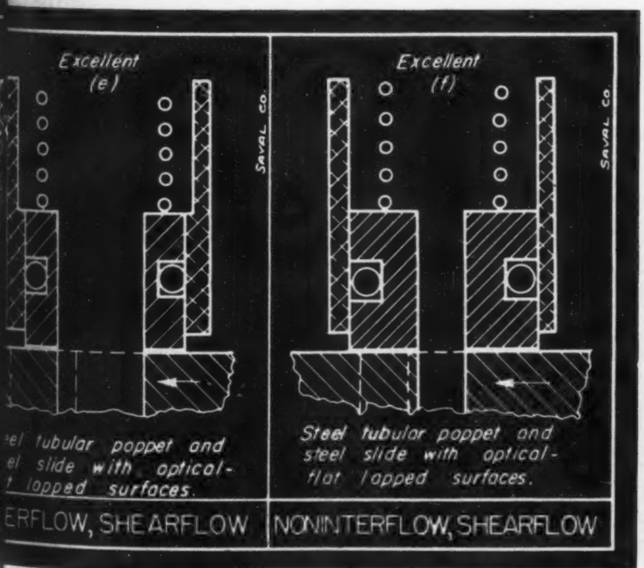


Fig. 9—Above—Typical linear motion actuators used on the XB-46 system

storage pressure to the required operating pressure, are important because they conserve storage energy. They make it unnecessary for all units and lines to withstand storage pressure, permitting use of lines with thinner walls and thus effecting a considerable saving in weight. Of the several types available today, the most satisfactory is the "optical flat" lapped-plate poppet type, *Fig.* 5*a*. A low-rate spring to reduce critical adjustments and overcome pressure changes resulting from temperature variations would improve the control range of regulators, *Fig.* 6.

Relief Valves: These valves protect the system from rupture due to surge or excessive pressures. The diaphragm-spring type is the lightest relief valve available, but because the diaphragm has shown a tendency toward fatigue after repeated operations, a more satisfactory valve is under development, *Fig.* 7.

Selector Valves: These valves, which regulate the operation of all actuating units, can be controlled by three basic methods—pneumatic or hydraulic pilot control, electric solenoid control or manual control. The most satisfactory type of selector valve on the

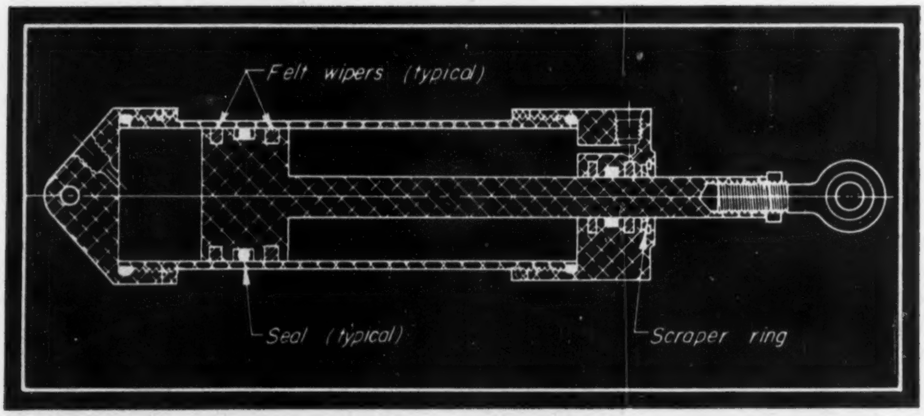
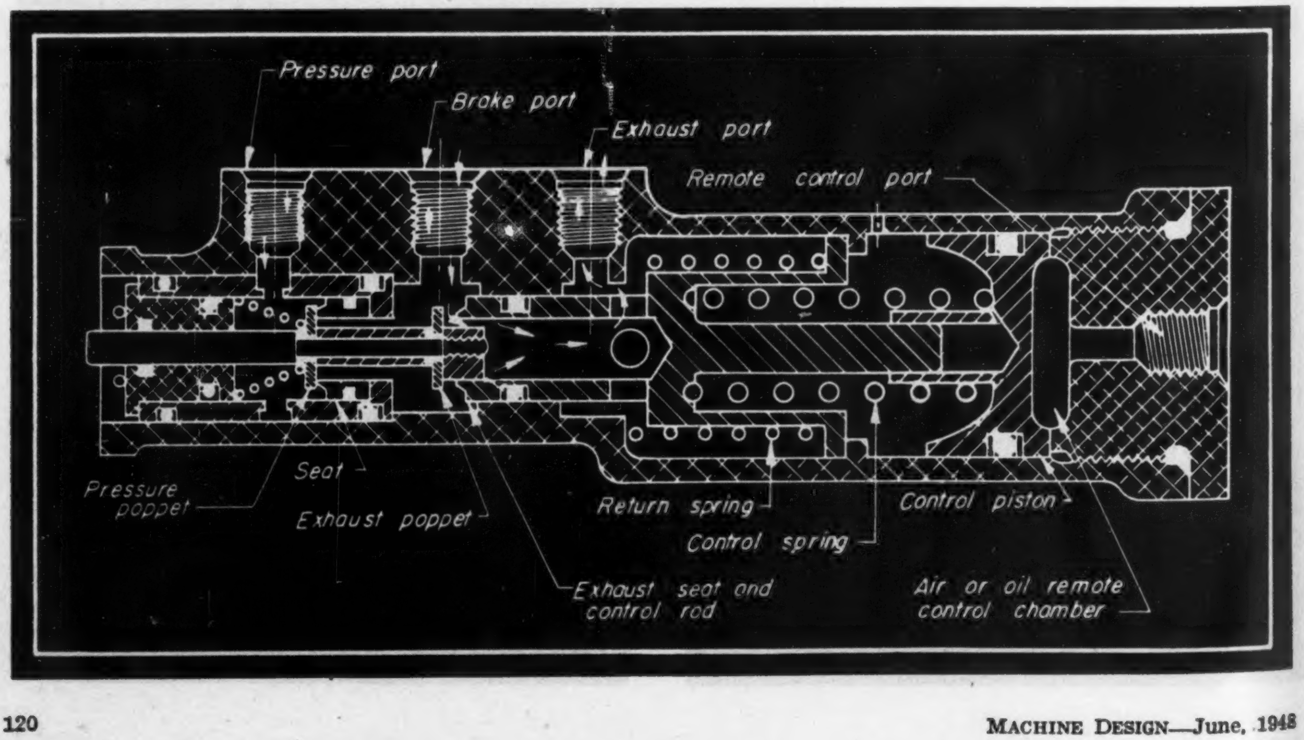


Fig. 10—Left—Cross section of typical pneumatic cylinder design used in system

Fig. 11 — Below — Pneumatic brake valve using optically flat plate poppet principle designed by Weston and Consolidated-Vultee



market is the "shear-flow" type, embodying a tubular poppet with optically flat lapped slide or rotor seat surfaces. Unlike other types, wherein the poppet is lifted off the seat to provide flow, the tubular poppet is moved along the seat—hence the term "shear-flow", *Fig.* 5. This valve has the added advantage of wiping off the seat as it moves, shearing any ice that might form, *Fig.* 8.

Actuating Units: Actuators which provide the force required to move the operating parts, are of two basic types—cylinders, *Fig.* 9, with linear motion, and motors with rotary motion. Pneumatic actuating cylinders are essentially like hydraulic actuating cylinders except that they require integral lubrication. At present this lubrication is accomplished by installing a grease-packed felt washer in a groove on both sides of the standard rubber "doughnut" seal, *Fig.* 10. Lubricating qualities of existing types require improvement inasmuch as the seals often tend to adhere to the piston rod or cylinder walls under high-pressure operation. One solution has been obtained by use of a 5 per cent paraffin impregnation, but further development should be carried out toward a more satisfactory solution to this sealing problem. Air motors for operation at high pressures are still in the development stage but will, when proved to be satisfactory, effect an appreciable saving in weight over an electric motor, especially in applications such as flap drives.

Pilot-Operated Brake System Desirable

Brake Valves: These valves control the pressure delivered to the brakes and thereby control the rate at which the airplane is stopped. The most economical installation is to mount the brake valve on the main landing gear, operating it through the foot pedals by means of a remote control, self-contained hydraulic master and slave system. Because the landing gear itself can be used as an accumulator, the lines required to deliver air to the brakes are very short. The exhaust air, furthermore, is vented at the valve, effecting split-second operation. In brake valves, as elsewhere, the most practical type employs the principle of the "optical flat" lapped-plate poppet, *Fig.* 11. To eliminate the need for hydraulic remote control of the brake valve, a revision of present-day low-pressure air brake systems could be employed. Another means of accomplishing this would be the utilization of low-pressure pilot-operated control valves.

Fuses: Shown in *Fig.* 12 is an adjustable type fuse used in the pneumatic system to protect against failure of pressure gages and lines. Similar to those used in a hydraulic system, operation of the fuse is based on a quantity-measuring principle.

Check Valves: As usual these valves allow flow in one direction only. The type shown in *Fig.* 13 employs a metal seat and a plate poppet in lieu of the rubber, fiber or steel poppet used on hydraulic check valves (see *Fig.* 5*c* and *d.*) The rubber seat type proved satisfactory in service but it is believed that the design shown in *Fig.* 13 is more reliable.

Shuttle Valve: When the emergency system pressure is selected in lieu of the normal system, shuttle

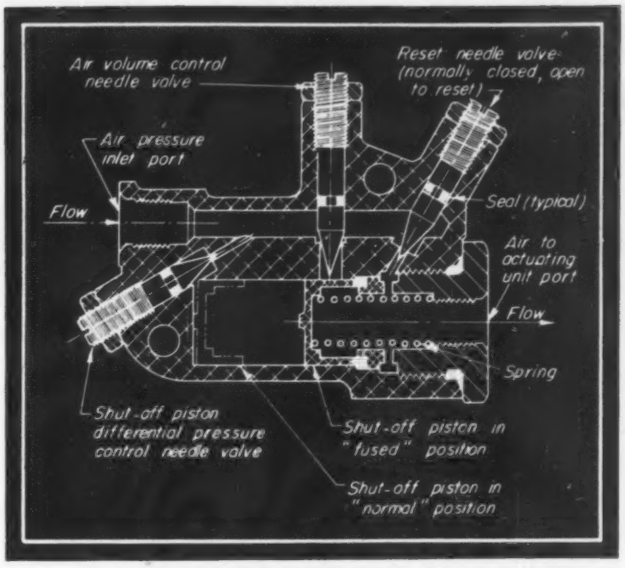


Fig. 12—Above—Weston adjustable pneumatic fuse for gage and line protection

Fig. 13—Below—Pneumatic check valve utilizing a metal seat and a plate poppet. A restrictor check valve has an orifice hole through the poppet

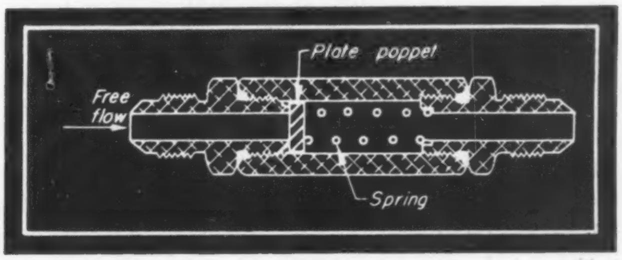
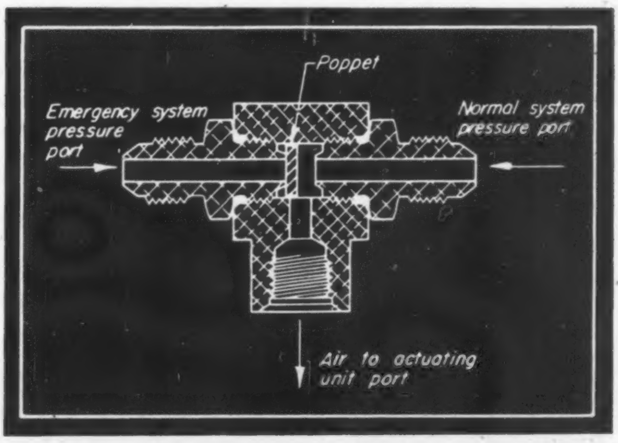


Fig. 14—Below—Highly satisfactory shuttle valve designed with a metal seat and plate poppet

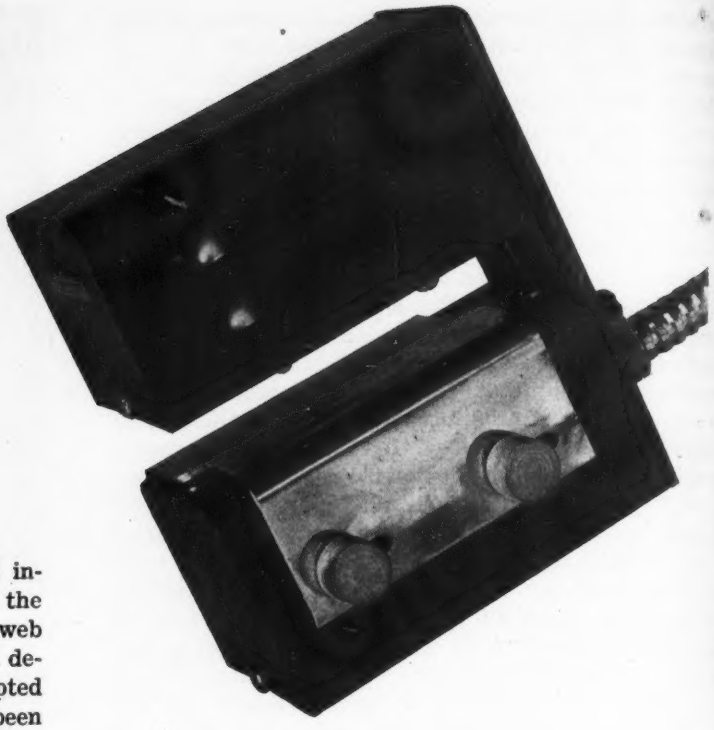


valves provide automatic cutoff of the normal operating system pressure lines, *Fig.* 14. Shuttle valves using the rubber seat, *Fig.* 5*c*, did not prove as satisfactory as the check valve and the design as shown in *Fig.* 14 is recommended.

The concluding portion of this article, which will appear in the following issue of MACHINE DESIGN, will trace the development and research which led to the present successful pneumatic system used on the XB-46.

Provides Accurate Cut-Off Control

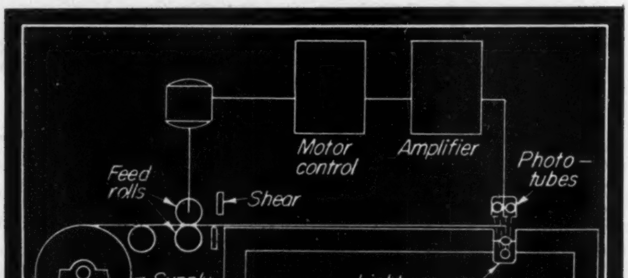
By Oren G. Rutemiller
Consulting Engineer
Cincinnati



FREQUENTLY it is desired to measure equal increments of length automatically, for example, the measuring of sheets being cut from a roll of web stock. The photoelectric web edge guide control designed for another purpose may be readily adapted to this application. This electronic control has been standardized by a number of manufacturers of industrial electronic equipment and is therefore readily available at low cost. Its application as a length or cut-off control will result in an inexpensive device that will give highly accurate results.

This control consists of a light source arranged to direct light on two fixed apertures each of which is associated with a separate phototube. The apertures are arranged so that, when a flat sheet is introduced between the light source and the apertures, first one aperture then the other is covered. With this arrangement three control conditions are possible: (1) Sheet withdrawn, both apertures illuminated, (2) sheet at controlled position, one aperture dark the other light and (3) sheet inserted beyond control position, both apertures dark. The phototubes are associated with suitable amplifiers which in turn operate relays, the contacts of which may be used for control of other magnetic control devices such as motor starters.

In applying this device as a cut-off control the scaneer head, shown in the photograph, consisting of light source, apertures and phototubes is mounted in a position such that the leading edge of the sheet will



cover one phototube aperture when the proper length of sheet has been fed from the cut-off head. This arrangement is illustrated in the accompanying sketch.

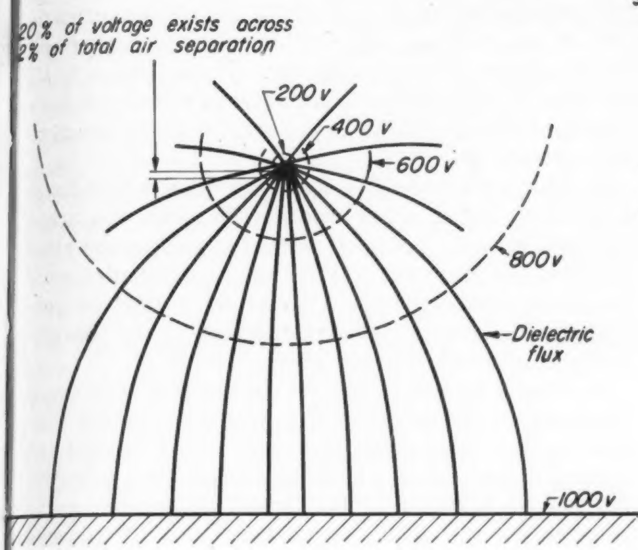
The magnetic motor control is arranged to energize the feed motor that causes the web to be fed out when both apertures are illuminated. When the leading edge enters the scanner, the first aperture is darkened and the feed motor is de-energized. The feed motor will not stop instantly and consequently the feed motor in the reverse direction at reduced second aperture will be darkened.

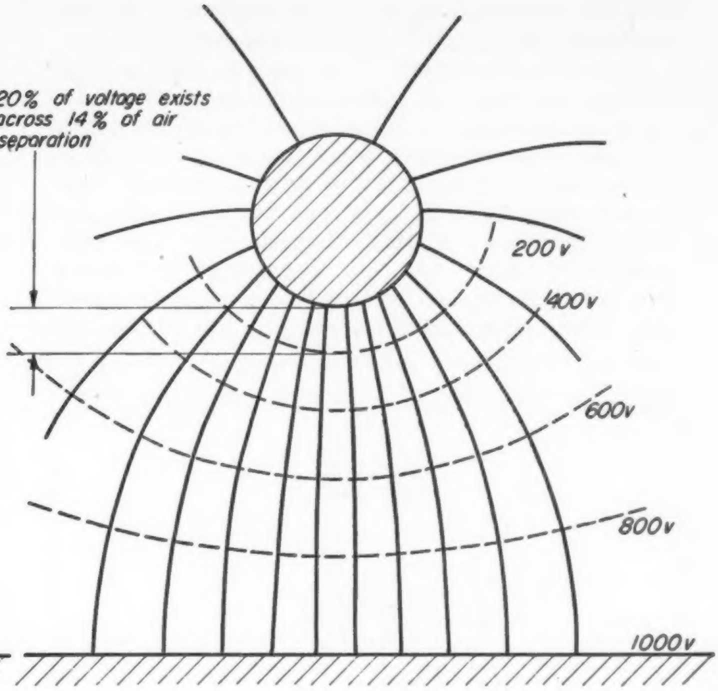
This causes the magnetic motor control to start the fed motor in the reverse direction at reduced speed. This action may actually plug the feed motor in some cases providing a faster stop of the feed motor and less overshoot. When the leading edge of the web has returned to the point where the second aperture is again illuminated the feed motor is stopped. The space between the apertures is adjusted to allow for the small amount of overshoot that will occur at this time due to the reduction in speed. Because of the slow speed of return, the second overshoot will be much less and the sheet will be accurately positioned. Since the slow-speed motor must move the web only a short distance very little time is lost in this second positioning operation and because higher accuracy is possible, the forward feed speed may be increased considerably. In many cases an overall saving in time is possible. Any of the usual schemes of braking may be applied to the slow-speed operation and will further reduce the overshoot and therefore increase the accuracy.

If the reverse speed is about one-tenth of the forward speed an accuracy of approximately one one-hundredth of the distance moved in one second at the high speed can be realized.

1—Below—Cross section through a small diameter conductor and its dielectric field

2—Right—Conductor increased in diameter to reduce the high voltage gradients near the conductor





High Voltages in Electronics

Formulas and charts furnish data on correct spacing between conductors for prevention of sparking and corona effects

By Walter E. Peery

Consulting Engineer and Designer
Morristown, N. J.

CONSIDERABLE uncertainty generally accompanies the laying out of high voltage circuits in the mechanical design of new electronic equipment. This is particularly evident when the apparatus is being designed as compactly as possible to conserve weight and volume as is the case in aircraft, military, and other specialized types of equipment. Often this equipment is beset with troubles of corona and sparking in high voltage circuits as a result of being spaced too closely.

When all of outdoors is not available for isolating high voltage circuits it becomes necessary for the designer to have at hand some well-founded standards upon which the air and surface spacings of high voltages can be based. It is the purpose of this article to present a set of such standards for the guid-

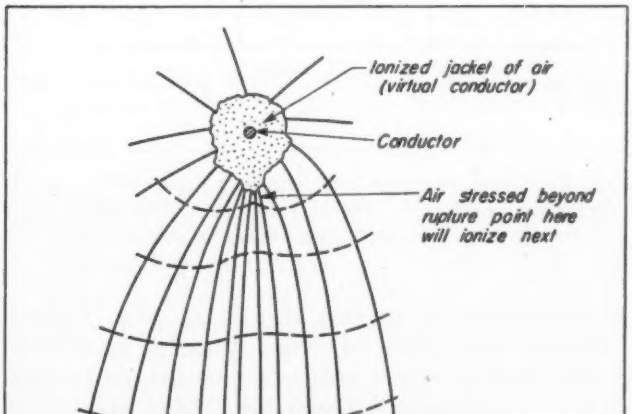


Fig. 3—Right—Conductor of Fig. 1 in the process of breaking down to ground

ance of engineers and designers responsible for the mechanical construction of electronic apparatus.

Problems encountered in laying out high voltage circuits are those of controlling the electrostatic fields produced by the voltages. While electrostatics is a complex subject, it is necessary to understand the mechanics of only a few of its phenomena to have an adequate working knowledge of the subject for design purposes. A brief discussion of these phenomena will serve not only to acquaint the reader with electrostatics but will illustrate the solutions of some high voltage problems and give him a basis for

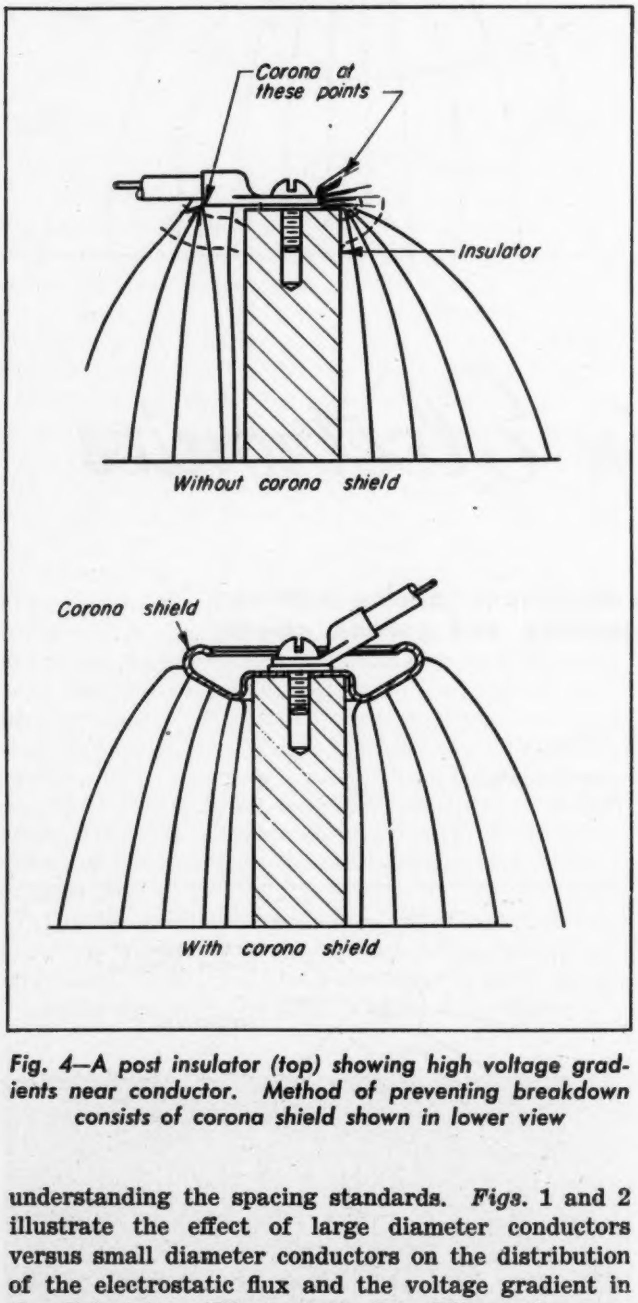


Fig. 4—A post insulator (top) showing high voltage gradients near conductor. Method of preventing breakdown consists of corona shield shown in lower view

understanding the spacing standards. *Figs.* 1 and 2 illustrate the effect of large diameter conductors versus small diameter conductors on the distribution of the electrostatic flux and the voltage gradient in the dielectric. (Electrostatic flux follows the same laws of distribution as the magnetic flux of a magnet.)

In *Fig.* 1 the flux converges toward the small conductor, causing high flux densities at the conductor. The voltage gradient in the air is proportional to the flux density and therefore there exists a disproportionate distribution of the voltage drop between conductor and ground. The voltage gradient at and near the conductor is much higher than that near the ground plane. In other words the air near the conductor is being subjected to greater electric stress. The smaller the conductor the more disproportionate will be the voltage distribution and the higher will be the stress at the conductor. If the stress in air exceeds 31 kilovolts per centimeter it will break down electrically and will be evidenced by the appearance of corona.

In *Fig.* 2 the condition has been almost completely relieved by substituting a larger diameter conductor. Here the spacing between conductor and ground plane remains the same but the voltage is distributed more uniformly across the gap and the air is stressed more uniformly. Basically, the elimination of the converging flux has produced this desirable result.

In *Fig.* 3 is illustrated the mechanics of progressive rupture of the air of *Fig.* 1. In *Fig.* 3, the voltage on the conductor has been raised beyond the corona point and a jacket of ionized or conductive air now surrounds it. The ionized air extends to the point where the voltage gradient is just 31 kilovolts per centimeter. A virtual conductor now exists around the original conductor, which reduces the original air gap and in turn increases the voltage gradient of the air surrounding the virtual conductor to above the breakdown point. This air in turn is ionized and the process continues until the complete gap is ionized and arcing over or sparking follows.

Corona Eliminated by Design

Two common locations of corona trouble, and effective methods of eliminating corona in each case, are illustrated in *Figs.* 4 and 5. In *Fig.* 4 the sharp edges of the washer and lug on the insulator cause converging of the electrostatic flux. This is cured by attaching a corona shield or "hat" to the insulator to effect a more even distribution of the flux and reduce the high voltage gradients in the air surrounding the insulator top.

In *Fig.* 5 a high voltage conductor passes through a hole in a metal enclosure. The sharp edges of the hole and the size of the conductor cause a converging of the flux resulting in corona at the conductor and the edges of the hole. A curved metal shield is installed in the hole as shown and the conductor size is increased to reduce the convergence and eliminate the corona. In both of these cases the interesting fact will be noticed that the actual gap spacing has been reduced by the corrective measures but the factor of safety against spark over is considerably increased.

The major design problem in preventing corona and sparking, as will appear from these examples, is one of preventing flux concentrations which produce high voltage gradients in the air surrounding the conductor. The solution lies in (1) providing rounded conducting surfaces of large radii and (2) adequate air and surface spacing to distribute the electrostatic flux.

Air and Surface Spacing Standards: *Figs.* 6 and

7 show the recommended minimum air and surface spacings for high voltages. Separate curves are given for organic and inorganic types of insulation, for rounded and sharp-edged conductor surfaces, and for a-c, d-c, and pulse voltages.

The data presented are based on operation at sea level pressure. When the equipment is to be operated in air pressures other than sea level, the spacings called for in the curves must be multiplied by the ratio of the sea level pressure to the working pressure. (The dielectric strength of air is directly proportional to its pressure throughout the practical working range of atmospheric pressures.)

If the equipment will not be subjected to the circulation of humid or contaminated air at any time, the spacings called for in the curves may be decreased in the interests of making the equipment more compact. This applies particularly to aircraft equipment and similar equipment which must be designed to volume and weight limitations. The amount of this decrease must be decided on the basis of the particular requirements of the design and the judgment of the designer.

Basis of the Spacing Curves

The spacing curves for air were based on the electrical breakdown characteristics of ball and needle spark gaps; those for insulating surfaces were based on insulator breakdown tests and on past experience with insulator problems in electronic equipment. The curves terminate at the 0.2 and 0.3-inch spacing lines, respectively, since these are the minimum practical spacings from the mechanical assembly standpoint for any voltage in ordinary electronic apparatus designs. Midget and ultra-compact apparatus constitute special cases. The curves also change slope between the 300-volt and the 0.5-inch spacing point to give more clearance to voltages between these points than would theoretically be called for. This is done for mechanical assembly and wiring purposes and to allow for accumulations of foreign materials in the spacings allowed.

Sharp Edged and Rounded Conductors: Curves *A* and *B* of *Fig.* 6 give the minimum spacing for sharp-edged conducting surfaces. Curve *C* gives minimum spacings for conducting surfaces whose radius of curvature is at least half of the spacing between conducting surfaces. Selection of the radius of curvature equal to 50 per cent of the spacing is based upon the fact that such surfaces prevent the voltage gradients which cause corona.

For practical design purposes a sharp-edged surface can be considered one which has a radius of curvature of less than 5 per cent of the spacing. The spacing curve for sharp-edged surfaces has a factor of safety of five over the needle-gap breakdown spacing.

When working with sharp-edged conductors of high voltages it must be realized that corona formation is a matter of degree even with spacings much greater than those given by the curve. The factor of five was selected as a compromise between unreasonably large spacings and unreasonably large amounts of corona. This fact further emphasizes the desirability of incorporating rounded surfaces in the high voltage conducting parts.

For those cases where the radius of curvature is between 5 and 50 per cent of the spacing, a more appropriate spacing can be calculated by multiplying the spacing given by curve *A* by the factor θ found from the following empirical formula:

$$\theta = \left(\frac{S}{20\,r}\right)^{0.87} \qquad (1)$$

where θ = multiplying factor to apply to the spacing found from curve *A*; S = spacing between conductors in inches, found from curve *A*; and r = radius of curvature of conductor in inches.

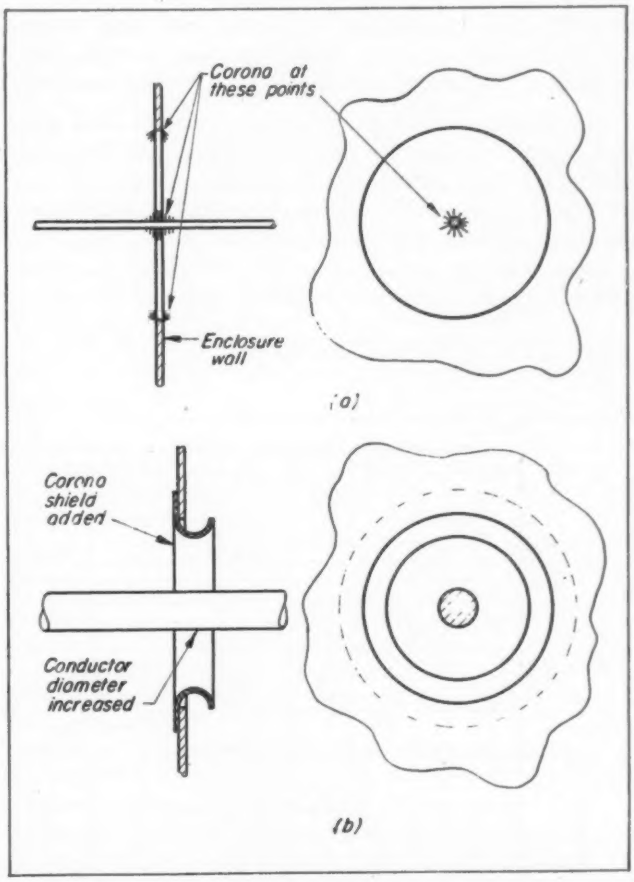


Fig. 5—Corona (a) where conductor enters an enclosure is prevented by addition of corona shield shown at (b)

Insulator Surface Spacing: Curves *D* and *E* of *Fig.* 7 give the surface spacing across insulating surfaces. Surface spacing includes the total creepage path along the surface of the insulator.

If an insulator is clean and dry its surface may be considered equivalent to air as an insulator. An insulator seldom remains clean and dry, however, but becomes contaminated with moisture and foreign matter which decreases its effective surface length. Therefore, the surface spacing curves *D* and *E* show greater spacings than the air spacing curves.

Organic insulating materials such as rubber, phe-

nolics, paper, varnishes, etc., are carbonized by the heat and ozone generated by corona and by any sparking or arcing that may occur on their surfaces. It is imperative, therefore, that in any apparatus design incorporating these insulating materials the designer be certain that they will not be subjected to these deteriorating influences. For this reason organic insulating materials are not recommended for use in circuits having more than 500 volts impressed.

When Slight Corona Is Permissible

Inorganic insulating materials such as mica, ceramics, glass, asbestos, etc., can not be carbonized and, therefore, if the situation dictates, may be subjected to small amounts of corona without damage. However, the heat generated by corona has been known to explode wet ceramic insulators, and in this case, therefore, the practice is definitely not recommended.

Pulse and Transient Voltages: Curve B of *Fig.* 6 gives air separation data for pulse and transient voltages of one microsecond duration, while curve F of *Fig.* 7 gives surface separation data in connection with inorganic insulating materials.

Less spacing between conductors carrying pulse and transient voltages is required than for a-c or d-c voltages because of the time necessary to establish corona, ionize the gap and flash over. This ratio of d-c flashover voltage to pulse flashover voltage is known as the impulse ratio.

For air spacing the impulse ratio according to Peek* is:

$$B_a = 1 + \frac{1.2}{\sqrt{t}} \qquad (2)$$

where B_a = impulse ratio for air spacing and t = duration of pulse crest, in microseconds.

To find air spacings for pulses other than one microsecond in duration divide the air spacing data from curve A by the impulse ratio as calculated by Equation 2.

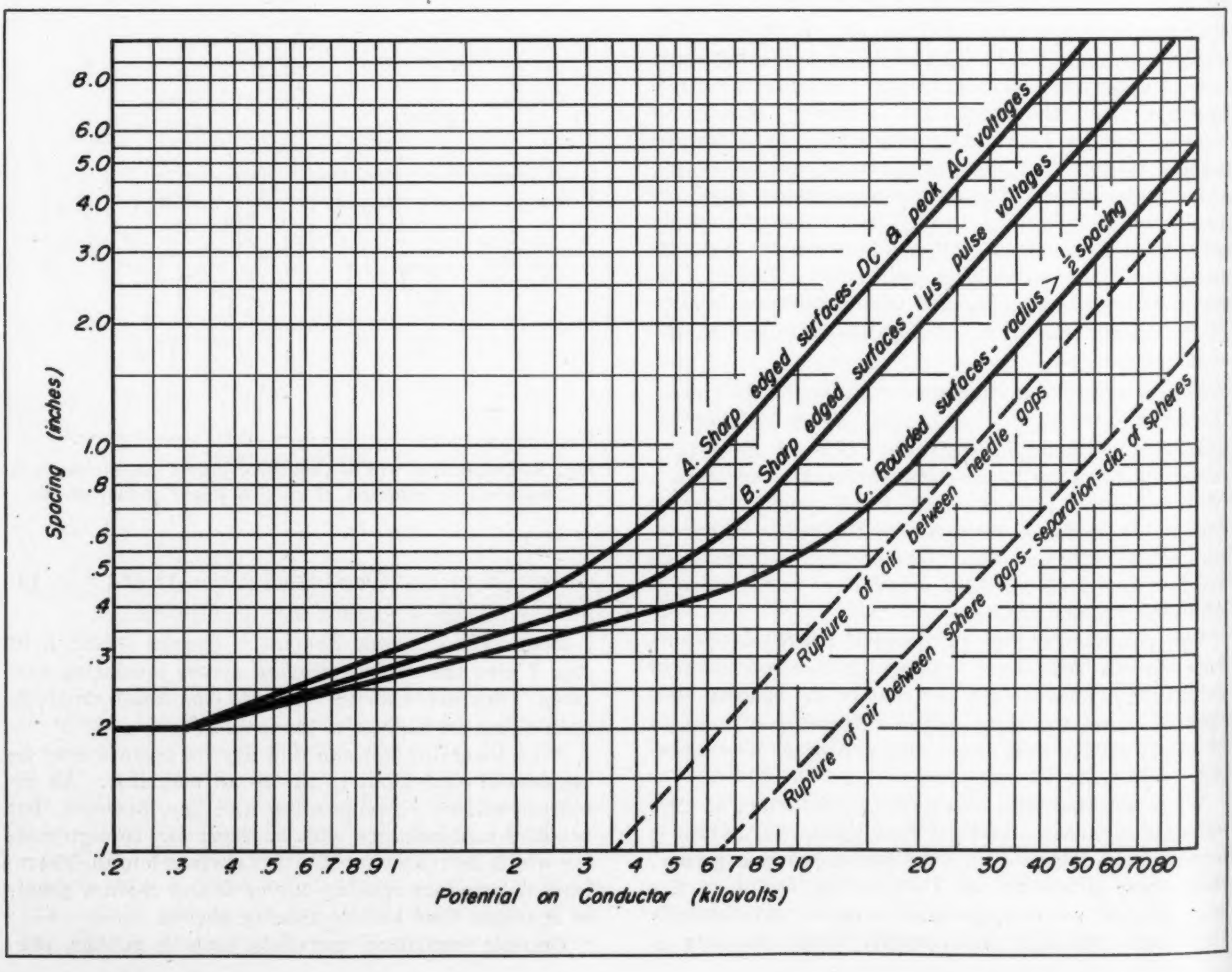
For surface spacing the impulse ratio also according to Peek* is:

$$B_s = 1 + \frac{0.8}{\sqrt{t}} \qquad (3)$$

where B_s = impulse ratio for surface spacing and t = duration of pulse crest, in microseconds. The impulse ratio for surface spacing is used in conjunction

*"The Effect of Transient Voltages on Dielectrics"—F. W. Peek, Jr. *Trans. A.I.E.E.* Vol. 49, 1930, Pages 1465-1469.

Fig. 6—Minimum air spacing between conductors



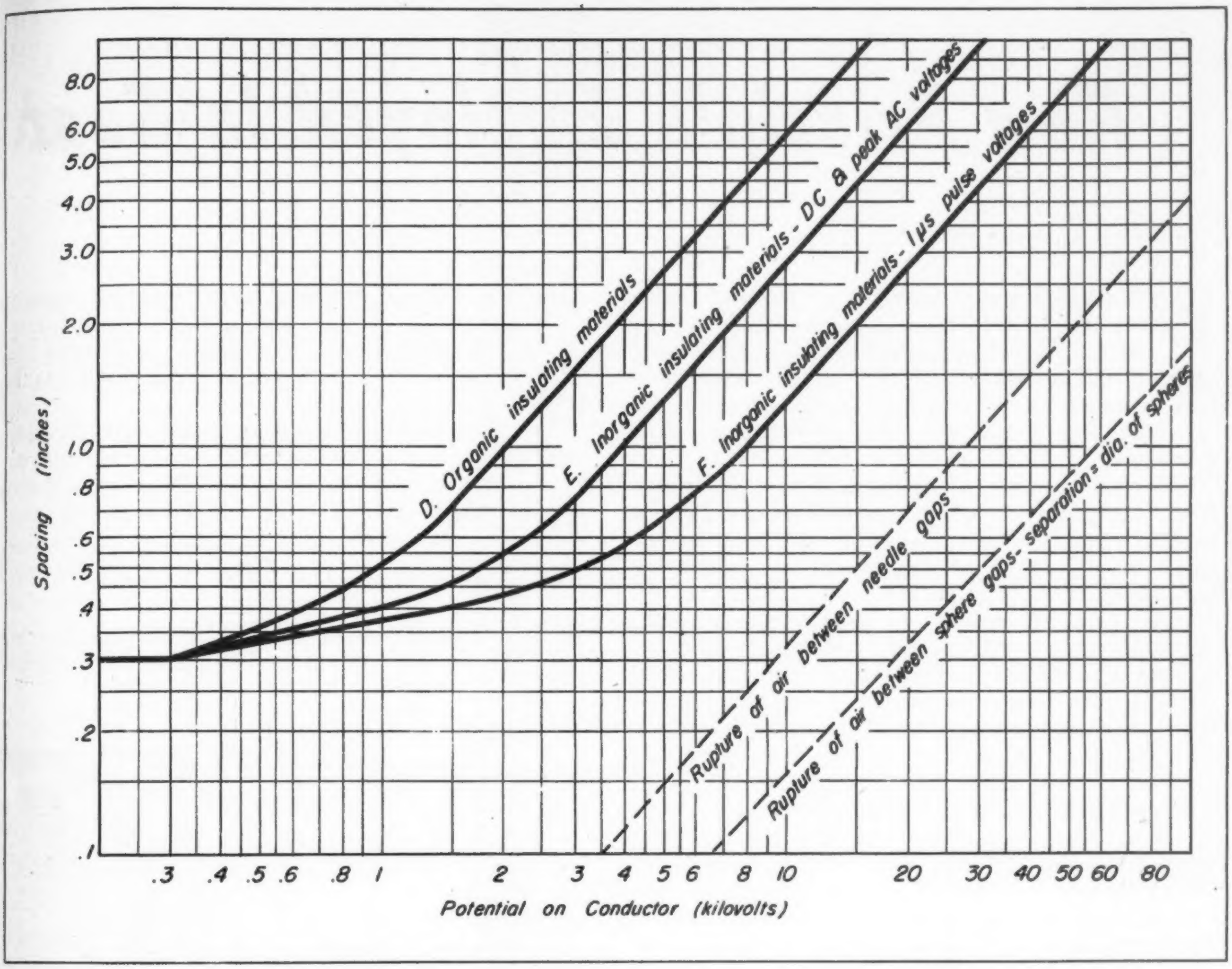


Fig. 7—Minimum surface spacing between conductors

with curve *E*. Impulse ratios do not apply to well-rounded surfaces since it is a phenomenon of the time lag in corona production, and corona is not developed on those surfaces.

USE OF THE DESIGN CURVES: The following tabulation is a simplified guide to the use of the design curves:

DC Voltages:

Separated by organic insulation .... Curve D
Separated by inorganic insulation .... Curve E
Separated by air, sharp edged surfaces on opposing conducting parts .... Curve A
Separated by air, rounded surfaces on opposing conducting parts .... Curve C

AC Voltages: (Use the peak voltage for design purposes)

Separated by organic insulation .... Curve D
Separated by inorganic insulation .... Curve E
Separated by air with sharp edged surfaces on opposing conducting parts .... Curve A
Separated by air with rounded surfaces on opposing conducting parts .... Curve C

Pulse Voltages: (one microsecond duration)

Separated by organic insulation .... Curve D
Separated by inorganic insulation .... Curve F
Separated by air with sharp edged surfaces on opposing conducting parts .... Curve B
Separated by air with rounded surfaces on opposing conducting parts .... Curve C

Radius of curvature of conductor less than ½ the air spacing:

Multiply data of curve A by the factor found from Equation 1.

Other than sea level pressures:

Multiply the data obtained from the curves by the ratio of sea level pressure to the working pressure.

Other than one microsecond pulses:

Separated by inorganic insulation—divide data of curve *E* by the impulse ratio as found from Equation 3.

Separated by air—divide data of curve *B* by the impulse ratio as found in Equation 2.

DESIGNED FOR HEAVY MOUNTAIN SERVICE, the million-pound electric locomotive which the General Electric Co. built recently for the Virginian railway employs motor generators to convert the 11,000-volt 25-cycle a-c current from the overhead wires to direct current suitable for operating the sixteen d-c series-wound traction motors. One of the largest and most powerful ever built, the new locomotive has a continuous rating of 6800 horsepower at the rail and 162,000-lb tractive effort at speeds as low as 15¾ mph. Top speed is 50 mph.

New Principle Employed in Gear ki

EMPLOYING a new type gaging element known as a master worm section, the machine shown at the top of the opposite page checks all types of spur and helical gears. The master worm section is based on the same mathematical principles as a hob, *Fig.* 1, and is ground to extremely close tolerances.

The machine itself, a development of the Eastman Kodak Company, is of the variable-center-distance type in which the master worm section is traversed longitudinally in engagement with the gear being tested, *Fig.* 2. Errors in the test gear such as departure from theoretical size, profile error, tooth-thickness error, tooth-spacing error, and eccentricity or runout are manifested as variations in the center distance. An electronic pickup records these variations on a moving chart providing a record of the composite error on the gear. From this chart individual errors may be evaluated.

In designing machines to make use of the concept of the worm section, two major problems were encountered. First, it was necessary to insure that the worm section travel in a straight line. Second, the inertia of the work table had to be such that its sensitivity approximated that of the electronic pickup.

First of these problems was met by mounting two hard-faced vertical rails to form a V-way in which the carriage holding the master worm section rides against recirculating ball bearings. One of these rails is indicated in *Fig.* 3. These rails are of laminated construction with a front surface of high-carbon steel hardened to Rockwell C 67. A massive, box-type casting supports them, insuring rigidity.

Each rail, in effect, defines a plane and the intersection of two planes is, by definition, a straight line. The worm section is traversed in a line parallel to the line formed by these planes.

A spring-loaded, recirculating ball-bearing bushing, *Fig.* 3, moving up and down a vertical rod between the rails, acts as a retainer to hold the carriage firmly against the V-way. The floating action of this bushing eliminates any tendency to impart direction to the travel of the carriage. The position of this bush-

Fig. 1—Diagram demonstrates that master worm section is based on same mathematical principles as a hob

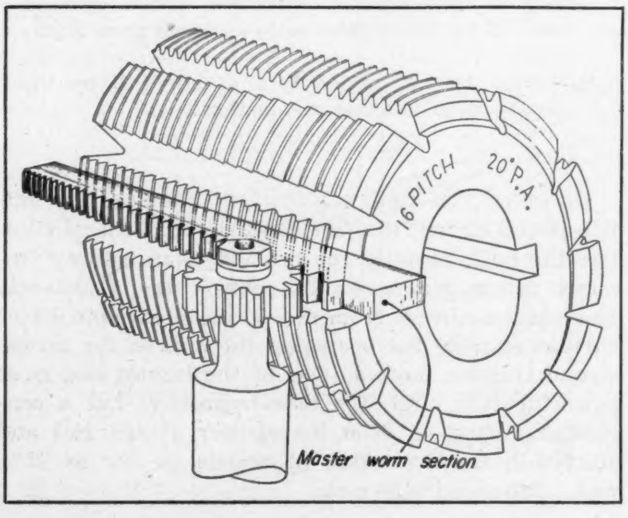
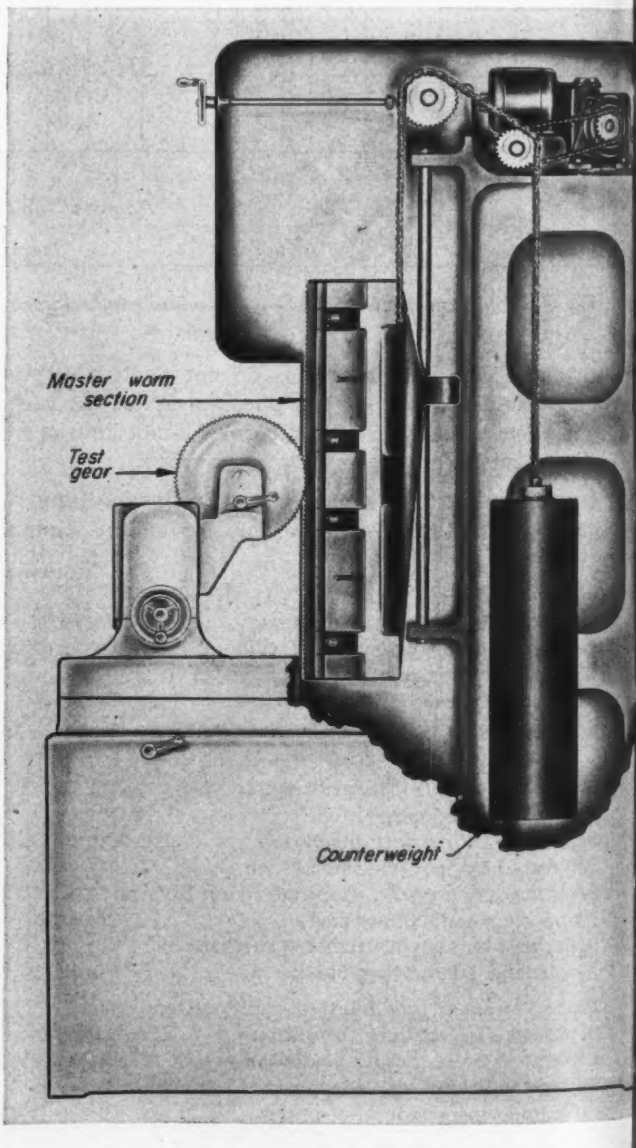
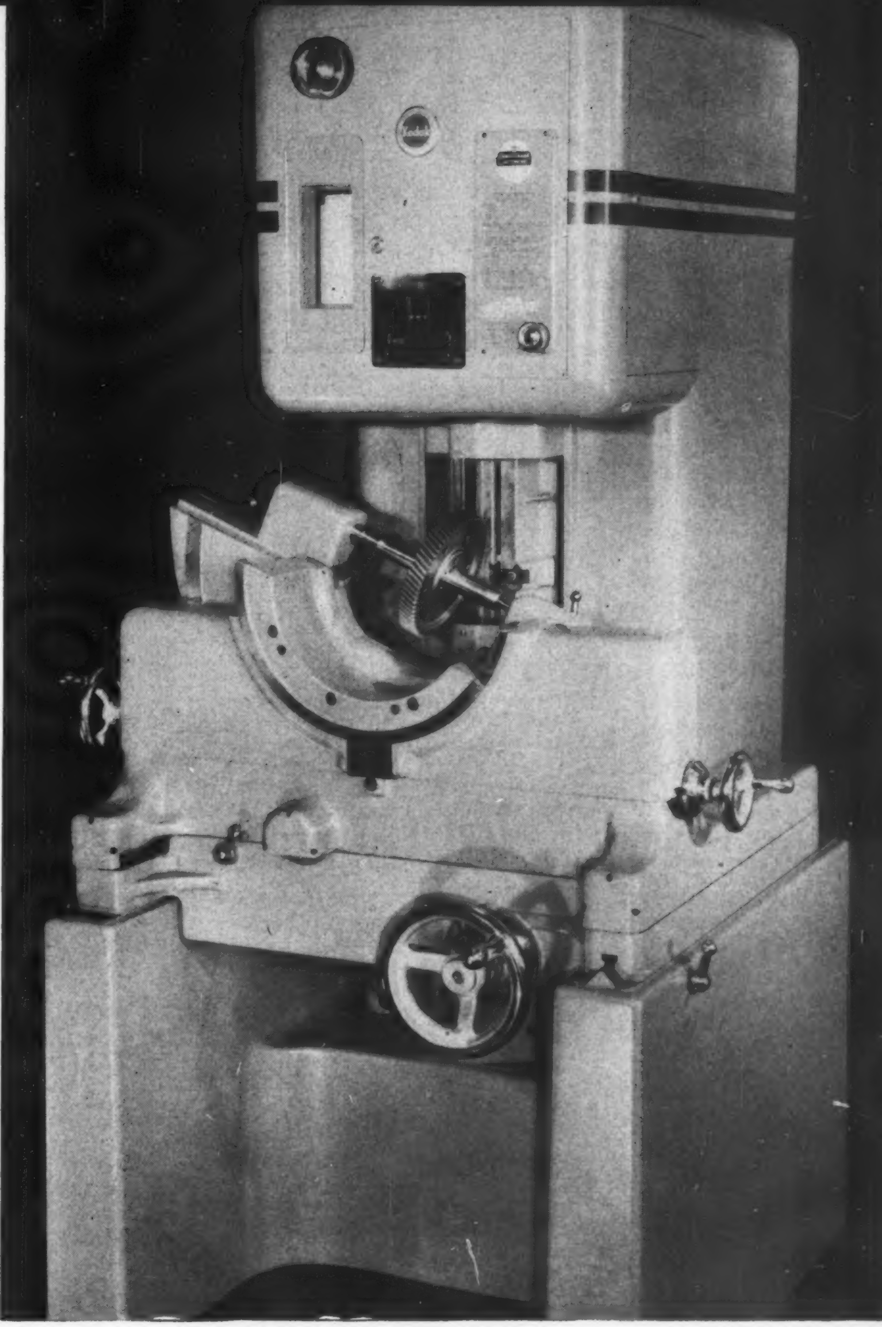


Fig. 2—Cutaway section of machine showing how the master worm section is traversed longitudinally in engagement with the gear being tested



king Machine



ing, and the position at which the driving chains are attached to the carriage, have been selected so that the load on the bearing surfaces is equalized.

Two chains, passing over a sprocket at the top of the instrument, connect this carriage to a counterweight, *Fig.* 2. A 1/20-horsepower synchronous gearmotor, driving through an overload-release clutch, is used to drive the master worm section at a speed of 2 inches per second. This enables the operator to check a gear of 8¼-inches pitch diameter—the maximum capacity of this machine—in 13 seconds. A cycle switch automatically stops the worm section when it has traveled the distance necessary to effect a complete revolution of the gear under test.

Table Rides on Balls

In designing the work table, *Fig.* 4, maximum sensitivity was assured by mounting the carriage on 64 selected balls. Half of these move in a double vee on one side of the carriage while those on the opposite side are mounted on a vee and a flat. This eliminates the need of parallel vees at each side of the table.

All raceways are of similar construction to that of the vertical rails, employing a hardened steel face fused to a mounting of mild steel. Inertia is such that the carriage responds to 40 cycles per second for 0.001-inch of travel. This results in the exploration of numerous points on all tooth profiles.

Electronic equipment used to measure center distance variation is made by the Brush Development Company and consists of three principal parts: An induction pickup, *Fig.* 4, located at the front of the work table; a displacement amplifier, mounted in the top right of the cabinet; and a direct-inking recorder, located at the top front of the instrument behind a glass pane. Lateral movement of the carriage as the gear is rotated against the master worm section is transmitted to the feeler arm of the pickup head, producing a signal which is amplified and recorded.

The pickup head is essentially a differential trans-

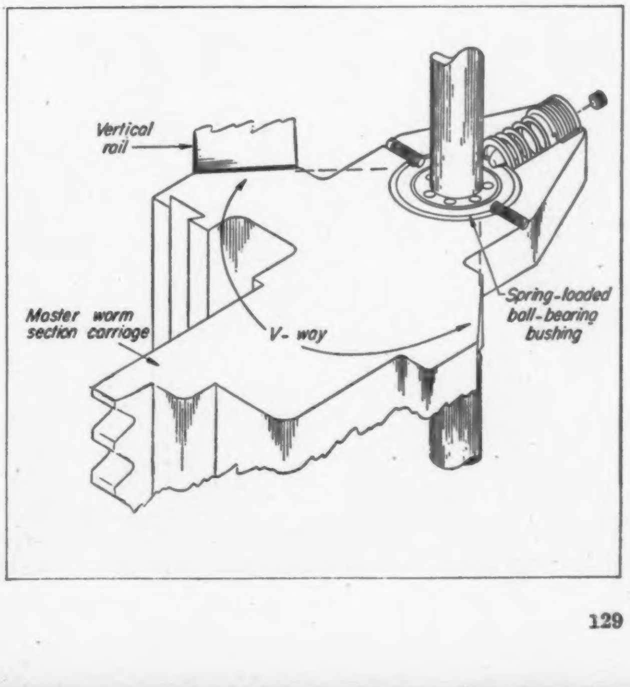


Fig. 3—Right—Master worm section carriage rides on vertical V-ways and spring-loaded ball-bearing bushings

former in which the center coil moves between two fixed coils wound so that their fields oppose. When the movable coil is exactly centered between the fixed coils, the resultant emf is zero. However, when the movable coil is nearer to one end than the other, the unbalance produces a voltage.

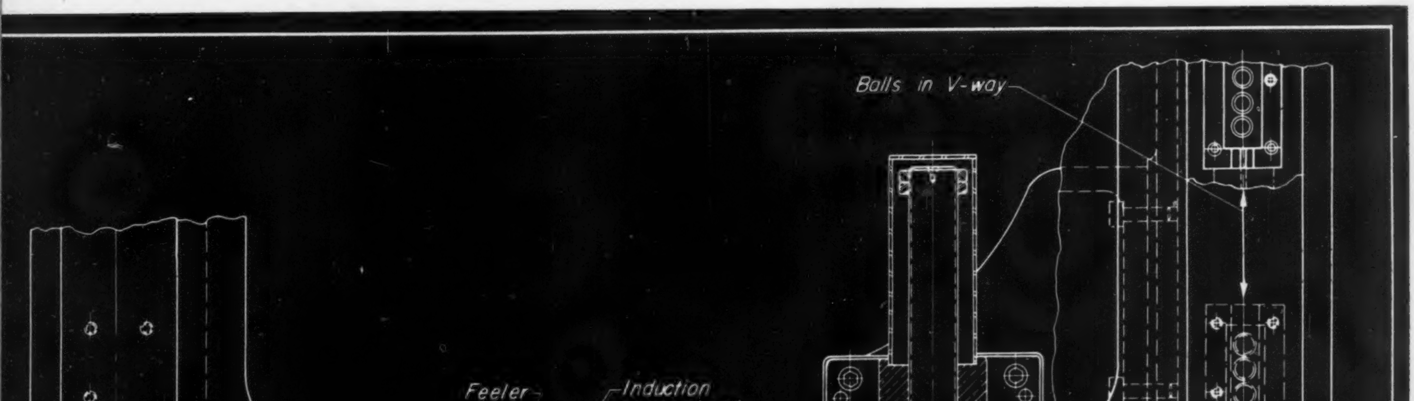
Output from the movable coil is rectified in such a way that the direction of displacement from center, as well as its magnitude, can be determined. This demodulated signal is further amplified and recorded on the paper tape. An impressive feature of the instrument is that tape after tape can be made of the same gear and any one exactly superimposed over another, since both the recorder and the master worm section are driven synchronously.

Sensitivity of the recorder is such that mechanical magnifications up to 800X can be used. This corresponds to approximately 0.00005-inch per chart division. A knob on the front of the instrument permits the use of selective magnifications of 100X, 200X, 400X, or 800X. In addition, three tape speeds are available. When inspecting between overall tolerance limits a low tape speed is desirable so that runout is clearly separated from tooth to tooth flicker. For close analysis of individual tooth errors, the faster tape speeds are helpful.

Another feature of the work carriage is a built-in cross-traverse slide which permits a gear to be traversed at right angles to the master worm section. Since this worm section, unlike a rack, is a part of a helicoid and has curvature in the transverse plane, any taper which exists in the gear is recorded when the gear face is explored in this way. Amount of cross travel is measured by a scale and handwheel with a dial graduated in thousandths of an inch. This feature also allows the crowning of a gear to be checked in the same manner as taper after the face of the gear has first been explored to find the high point of the crown. Moving a gear a known distance and noting the new indicator reading provides data for simple calculation to determine amount of crown.

Also built into the work carriage is an accurate sector, on which the work centers are mounted. This is revolved by a worm and worm gear operated by a handwheel and permits rapid positioning of the work gear axis to any helix angle up to 45 degrees either hand.

Fig. 4—Section through work table carriage showing balls on which table rides and feeler which senses changes in center distance of gear and master worm section



Offset Pivot Reduces Sector Gear Noise

By Herbert F. Bariffi
Consulting Engineer
New Haven, Conn.

WHEN angular oscillation is applied to a load through a sector gear and pinion, *Fig.* 1, backlash between the mating teeth may cause a disturbing periodic impact sound. If this does not occur when the gears are new, it certainly will as wear occurs.

When backlash is present, impacting may occur at several points—at or near the center and ends of strokes. It will be shown that if the inertia is small compared to the rest of the load, which is true for constant friction and friction proportional to velocity, the sector pivot may be so located as to prevent the undesirable "clicking" of the teeth as the pitch line forces reverse direction.

When the pinion shaft carries a load which is mainly dynamic, it will be difficult to eliminate impacting near the center of the stroke, should backlash be present. The graph, *Fig.* 2, shows the phase relationships when the load is composed of three forces—constant friction, velocity load, and inertia forces. The latter two will be seen to be in quadrature if the movement is simple harmonic, or nearly so. The constant friction may be viewed simply as adding to the velocity load amplitude. These forces combine vectorially, and the resultant may be shown by graphical addition. *Fig.* 2 represents only a hypothetical case. Should the composite curve lie wholly on one side of the base line during one stroke, there should be no reversal of forces except at the ends, and consequently no impacting even where there is tooth clearance. At each end of the stroke the friction and velocity forces reverse, but backlash can be

Fig. 1—Right—Eccentrically-pivoted sector gear makes possible zero backlash at ends of stroke and slight backlash elsewhere

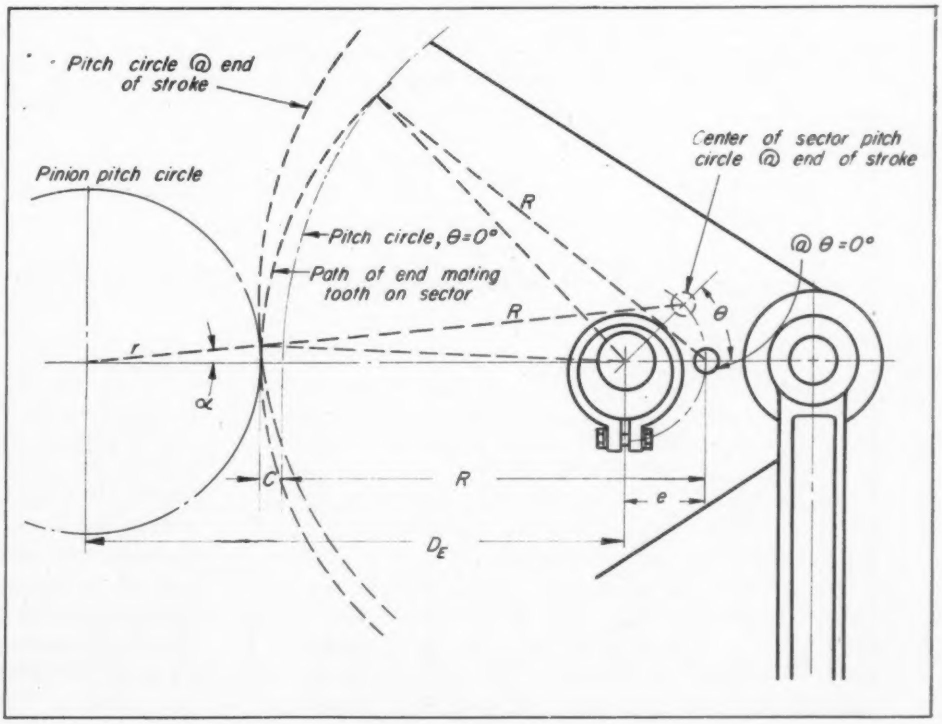
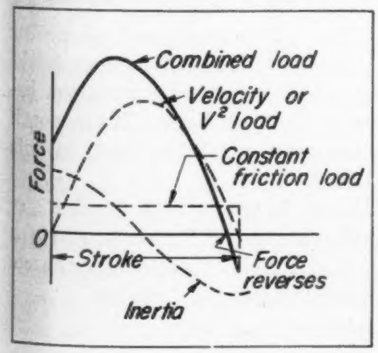


Fig. 2—Below—Combined load on sector gear will not reverse direction during stroke if inertia is small relative to the rest of the load



eliminated at those points in the following manner.

If the sector pivot is located out of coincidence with the center of the tooth pitch circle, it will be possible to mesh the sector and the pinion with no backlash at either end of the stroke, and with a slight but definite amount elsewhere. In this way the effect of inaccuracies in the gear teeth may be so handled that clearance will not occur at the ends of the stroke, nor will mashing of the teeth take place elsewhere, an important consideration when readjustment after wear is necessary. A lesser degree of tooth accuracy may also be tolerated than would be the case where axis of oscillation and pitch line center coincided. Separation will not affect the conjugate action of the teeth when involute tooth form is used.

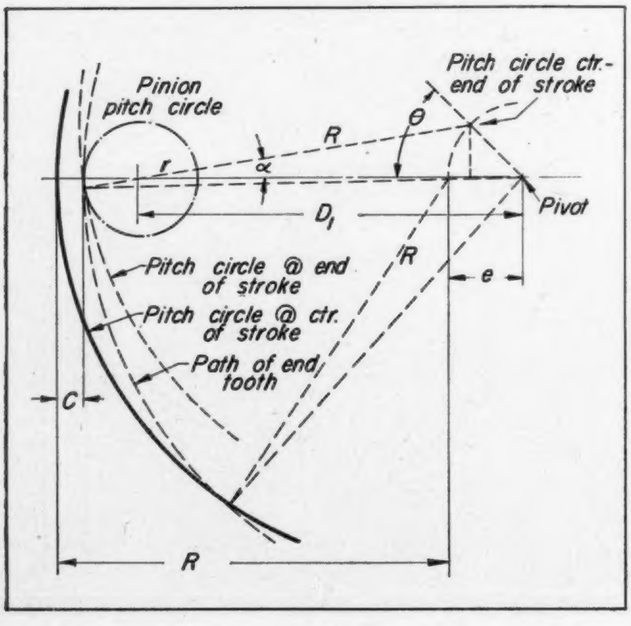
Locating the Pivot Point

In *Fig.* 1 the pivot or center of oscillation is located at a distance, or eccentricity, e from the center of the pitch circle. As shown for a spur sector, the pivot is located between the pitch circle center and the teeth; for an internal sector these two points exchange locations, *Fig.* 3.

The angle θ is one-half the total angular displacement of the sector; R and r are the pitch radii, respectively, of the sector and pinion; and C is the clearance between the pitch lines at the center of the stroke. It is selected at will and is always a minute quantity, but generally larger than the greatest tooth, or pitch-line, error expected. Given the foregoing quantities, the problem is to determine the value of e, the eccentricity.

SPUR-GEAR SECTOR: Referring to *Fig.* 1, which shows a spur-gear sector, a line is drawn joining the center of the sector pitch circle at the end of the stroke and the center of the pinion pitch circle. Inasmuch as there is to be no backlash at the ends of the stroke, the pitch circle will touch on this line, and the following equation can be written:

Fig. 3—Eccentrically-pivoted internal sector gear may also be designed with controlled backlash



$$(R + r)\cos\alpha = R + C + r - e + e\cos\theta$$

or

$$e = \frac{C - (R + r)(\cos\alpha - 1)}{1 - \cos\theta} \quad (1)$$

Also, $(R + r)\sin\alpha = e\sin\theta$, from which

$$\cos\alpha = \frac{1}{R + r}\sqrt{(R + r)^2 - e^2\sin^2\theta} \quad (2)$$

The positive sign is used before the radical because α will be in the first quadrant. Substituting Equation 2 into Equation 1,

$$e = \frac{R + r + C - \sqrt{(R + r)^2 - e^2\sin^2\theta}}{1 - \cos\theta} \quad (3)$$

Because C is usually small compared to r or R (a few mils at most), e is also small and e^2 becomes negligible. Hence

$$e = \frac{C}{1 - \cos\theta} \quad (4)$$

showing the rather remarkable result that e is virtually independent of the gear sizes.

It should be noted that, since $\cos 0° = 1$, reasonable angular strokes only can be considered. For example, for a total angular movement of 10° ($\theta = 5°$), $e = 263$ C—a rather large ratio. However, in such a case the tooth error would probably be extremely small and C would be chosen small accordingly.

INTERNAL-GEAR SECTOR: With an internal-gear sector, *Fig.* 3, similar analysis gives the following variation of Equation 3:

$$e = \frac{R - r - C - \sqrt{(R - r)^2 - e^2\sin^2\theta}}{\cos\theta - 1} \quad (3a)$$

Making the approximation $(e\sin\theta)^2 = 0$,

$$e = \frac{C}{1 - \cos\theta} \quad (4a)$$

which is the same result as for a spur-gear sector.

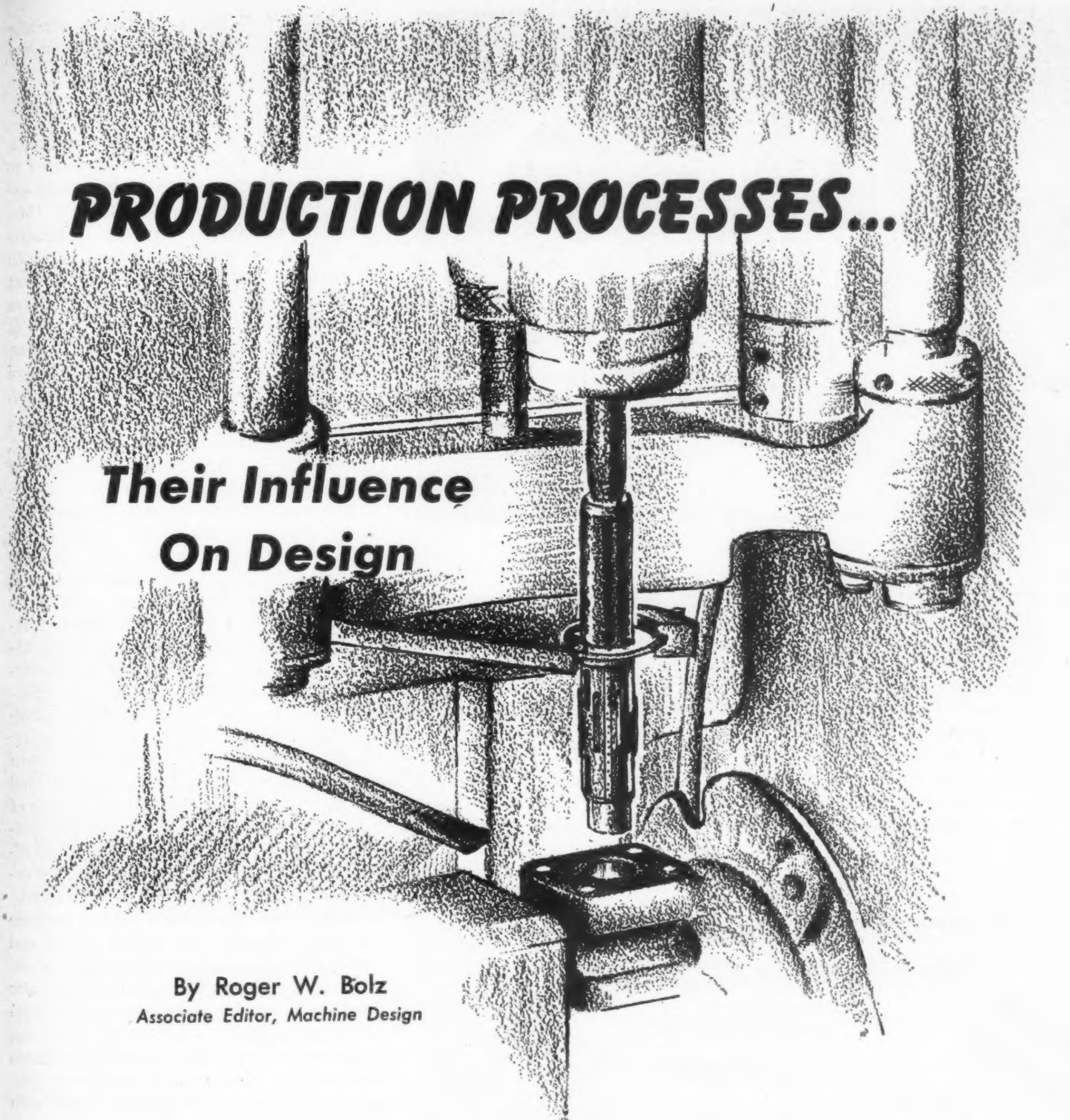
INCREASE IN BACKLASH: If adjustment of sector and pinion is properly made, there will be zero backlash at the ends of the stroke, and the separation between pitch lines at the center will be C. If the tooth errors are zero, the circumferential backlash in this vicinity may be found as follows:

If B = normal backlash between teeth and B_c = circumferential backlash, then $B = B_c\cos\phi$, where ϕ is the pressure angle. Letting dC denote the change in center distance between the gear and pinion

(*Concluded on Page* 196)

PRODUCTION PROCESSES...

Their Influence On Design



By Roger W. Bolz
Associate Editor, Machine Design

Part XXXIV–Honing and Lapping

PROPERLY classed as refined grinding operations, the methods of processing commonly known as honing and lapping logically follow production grinding in the sequence of production methods classed in order of increasing smoothness of surface finish. Although surface finish quality possible with finish grinding operations edges into the zone covered by honing and lapping, to demand the absolute minimum is usually not the economical answer in production. Because of the reduced speed in grinding, extremely light metal removal and special attention required to obtain the finest surface finish, economy dictates the use of maximum speed in production grinding and roughest satisfactory surface finish with a subsequent operation to attain the desired surface quality and geometrical accuracy.

Type and quality of surface finish produced by the basic metal-removal methods is for the most part incidental. With the honing process, however, type and quality of surface finish is the primary purpose of the process although, where necessary, material removal on the order of that possible with grinding can be had but of course at a sacrifice in finish quality. Lapping, on the other hand, distinctly is *not* a metal removal process, stock removal in production never exceeding 0.0005-inch. Most important is the fact

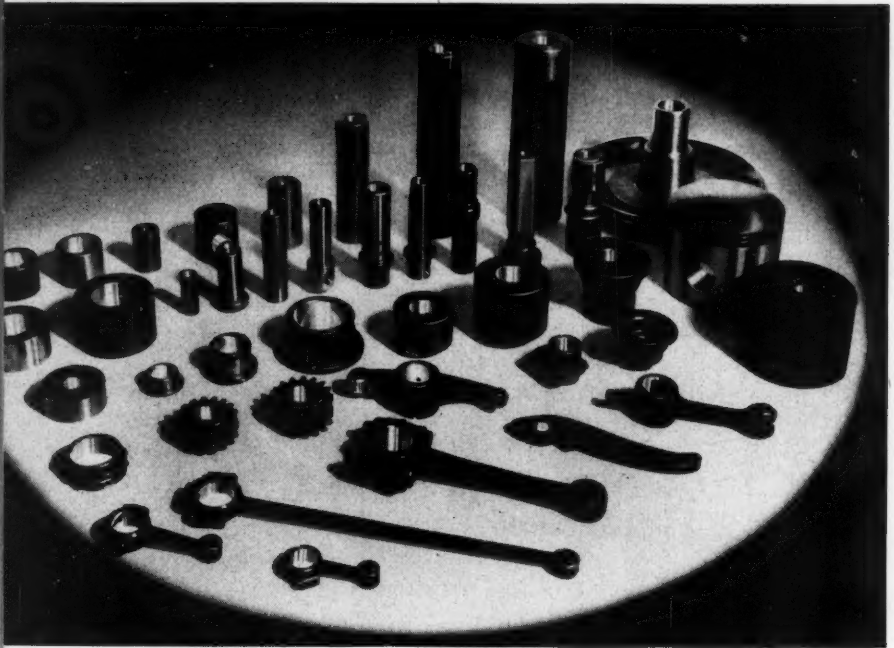


Fig. 1—Left—Group of precision machine parts with surfaces finished by Microhoning

that, beginning with honing, the major factor which places these processes among the necessary production methods is their ability to correct the geometrical surface inaccuracies and inconsistencies normally left by metal-removal operations.

Need for maximum possible geometrical accuracy and quality of surface finish is most acute with designs requiring extremely precise interchangeable fits, bearing fits where run-in and wear are to be minimized, pressure fits where seals are impractical, etc. The major portion of these requirements fall into the realm of cylindrical or flat surfaces, and honing is now widely employed to produce such accurate internal and external cylindrical surfaces, *Fig.* 1. Mechanical or machine lapping is primarily suited for *refining* surface finish on external or internal cylindrical and flat surfaces, *Fig.* 2. In addition, by means of semimechanical lapping a variety of surfaces such as external tapers, shouldered parts, spherical internal and external surfaces, etc., can be finished.

Honing: Principal difference between honing and grinding is that, in honing, the abrasive stones have a large area of surface contact while in regular grinding a narrow-line contact is employed. Like grinding, honing is usually performed by rotation of the abrasive stones but a long traversing motion is used providing a pattern of scratches with much greater lead. The finish developed in honing is a result of reciprocation of the rotating honing tool within a bore or reciprocation of the rotating work within the honing head, this reversal of motion developing a cross-hatch finishing effect which helps eliminate the greater portion of pattern defects left by previous production operations. Actually, modern honing techniques will provide practically any kind of controlled surface roughness, including the lay of the scratch pattern. Thus over and above the conventional cross-hatch pattern, multidirectional or random patterns and codirectional patterns can be obtained.

Developed in the early 1920's because of the necessity for better finish and more accurate dimensional control of automotive cylinder bores, honing has now become a rapid, accurate, repetitive production method. Capable of removing high spots, correcting out-of-roundness and taper, honing also generates fine surface finish much faster than with reaming or grinding. Honing does not, however, establish the position or alignment of a hole, bore or diameter. Little or no improvement insofar as alignment or location are concerned can be expected as the tool tends to follow the neutral axis of the bore or diameter and the preceding operations must establish this axis as accurately as is required. Although up to as much as 0.090-inch of stock can be removed in honing, stock removal should preferably

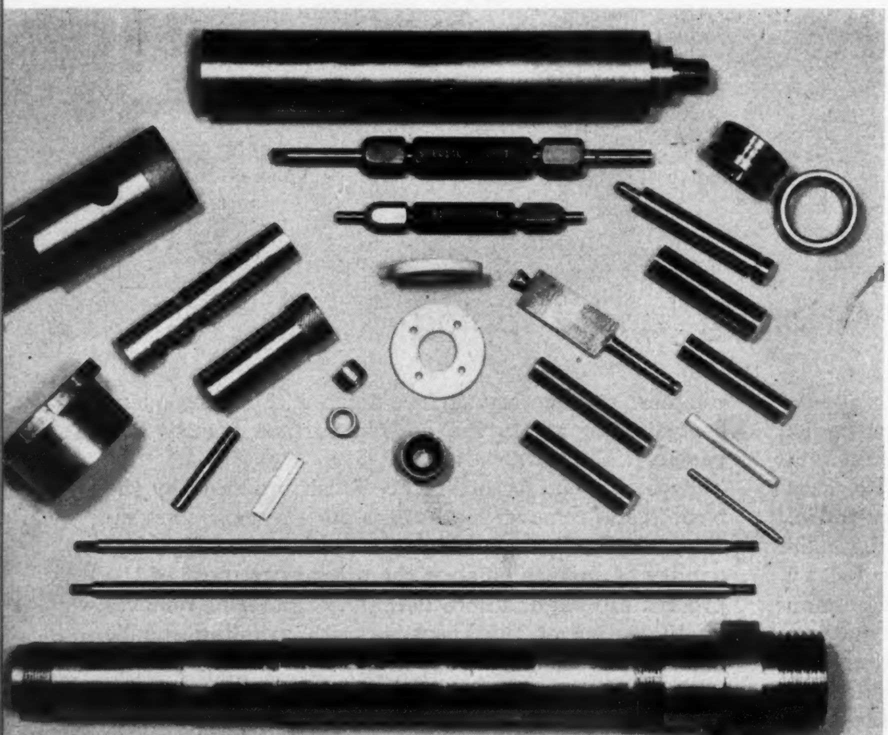


Fig. 2—Left—Variety of parts on which surfaces have been finished by centerless lapping with loose abrasives

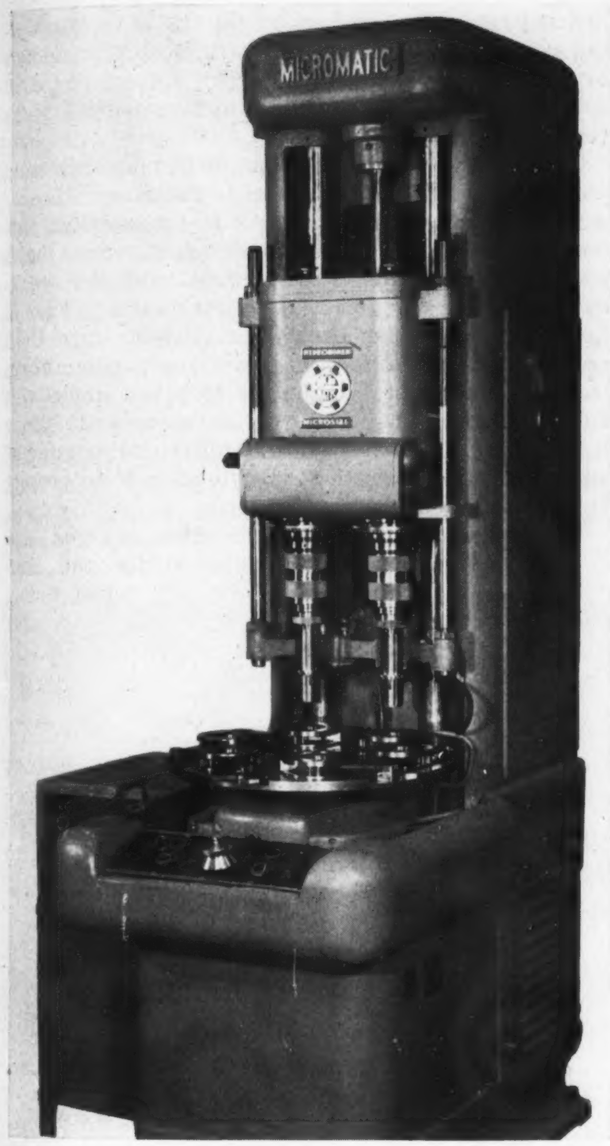


Fig. 3—Model 710-2 Hydrohoner equipped with the Microsize air control and automatic indexing table and fixture for honing automotive connecting rods

be small as possible for maximum economy.

The honing tool generally floats or moves slightly with relation to its driver and has a body which carries several relatively long and narrow abrasive stones. Stones are mounted in metal holders carried in shoes which have free axial movement within certain limits and are arranged to be expanded or contracted radially by one of several methods. For large

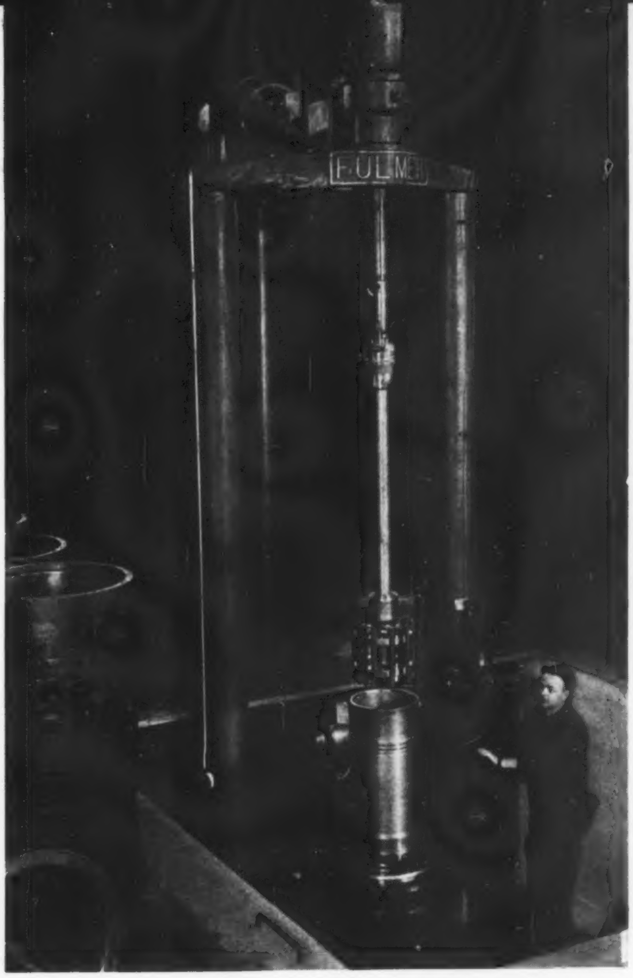


Fig. 5—Above—Large locomotive diesel-engine cylinder liners being finish honed on a vertical machine

production work, full automatic hydraulically actuated hones are used with vertical machines, *Fig.* 3. For machines not equipped for hydraulic actuation of the tool, mechanically actuated 3-finger automatic hones are used. For limited production the so-called brake type hone is used, expansion and contraction of the abrasive sticks being accomplished manually.

Where extremely long parts are to be honed, horizontal machines, *Fig.* 4, normally are employed, which require special hones with fiber support guides to carry the weight of the tool and prevent marring of the finish on entrance to or retraction from the work. For external honing the work normally rotates between centers and reciprocates on a carriage while the hone is mounted in a fixed position near the center of the machine bed.

A variety of standard and special honing machines are available in either the vertical or the horizontal models. Verticals are used on work up to 6 or 7 feet in length and up to 30 inches in diameter, *Fig.* 5. Largest vertical built has a stroke of 8 feet and is capable of finishing diameters up to 30 inches by 90

Fig. 4—Below—Barnesdril No. 5 horizontal hydraulic honing machine finishing a 4.750-inch gun bore 21 feet long to within 0.0007-inch for roundness and straightness with a stock removal of 0.015 to 0.020-inch per minute

inches long. Horizontal machines, in single and double-spindle models, are used mainly for finishing gun bores, cylinders, long tubes, etc., in diameters up to 50 inches and lengths up to 70 feet, *Fig.* 4. External work also can be honed, in diameters up to 6 inches or more and lengths from 2 inches to 12 feet, *Fig.* 6. Special mass-production machines also include a variety of multiple spindle models in both straight and angular setups, *Fig.* 7.

Honing speeds for cast iron range from 200 to 250 surface feet per minute in rotation and 50 to 75 feet per minute in reciprocation. Rotary speeds for steel range from 150 to 200 sfpm and reciprocation about 50 fpm. Bore size, character of material, stock to be removed, and finish desired sets the actual combination of speeds selected. Production speeds are high and crankshaft bearing holes in connecting rods, for instance, are finished four at a time at a rate of 300 per hour, while V-type 8-cylinder motor blocks are finished at an average of 90 blocks or 720 cylinders per hour. Diesel engine cylinders 12.75 inches in diameter by 44 inches in length are completed in approximately 5 minutes floor-to-floor with a stock removal of 0.006 to 0.008-inch.

LAPPING: Straight-line honing or lapping with solid abrasive stones is often desirable following the normal honing procedure to remove the cross-hatch pattern and produce an even finer lapping-stone finish with all scratch pattern codirectional with the operation of the mating part over the surface, *Fig.* 8. Solid abrasive sticks of somewhat wider face than regulation honing stones are used and a nonuniform indexing mechanism guarantees that the stones will not trace more than once in the same path. Since this lapping removes only an infinitesimal amount of stock, a honing operation must precede it to correct and perfect the geometry of the part.

Where desirable, cast iron or other charged laps can be substituted for the honing tool to obtain a velvet finish. Hand lapping with abrasive charged laps of soft metal, of course, is well known but is extremely slow and poorly suited for economical interchangeable manufacture. Mechanical or machine lapping offers a degree of refinement over surface finish produced in ordinary honing operations and can be applied to bores, cylindrical surfaces and flat surfaces.

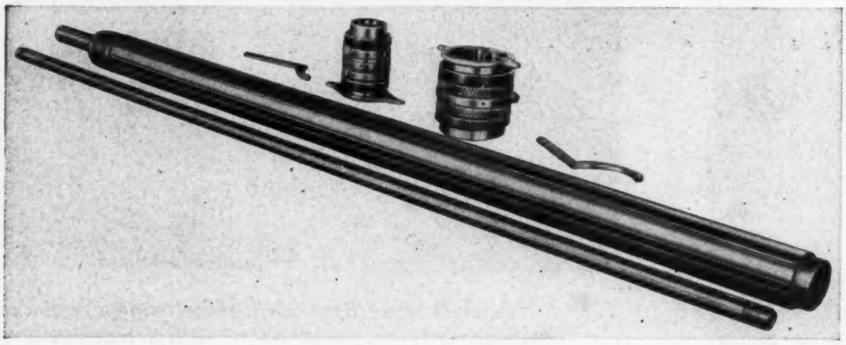


Fig. 6—Left—Piston rods 1½ and 4½ inches in diameter by 8 feet long honed within 0.0001-inch to 0.0002-inch for diameter and straightness, and external honing tools

For production lapping a variety of machines are available which use charged laps, bonded-abrasive laps, and abrasive coated papers. Vertical-spindle machines with parallel flat charged cast-iron laps will handle flat parts up to 4 inches thick and 9 inches in longest dimension or cylindrical work up to 4 inches in diameter by 9 inches long. Centerless lapping machines are available which employ a charged lapping roll and a control roll both of which are driven, the charged roll normally being the faster. Where desirable, dual or

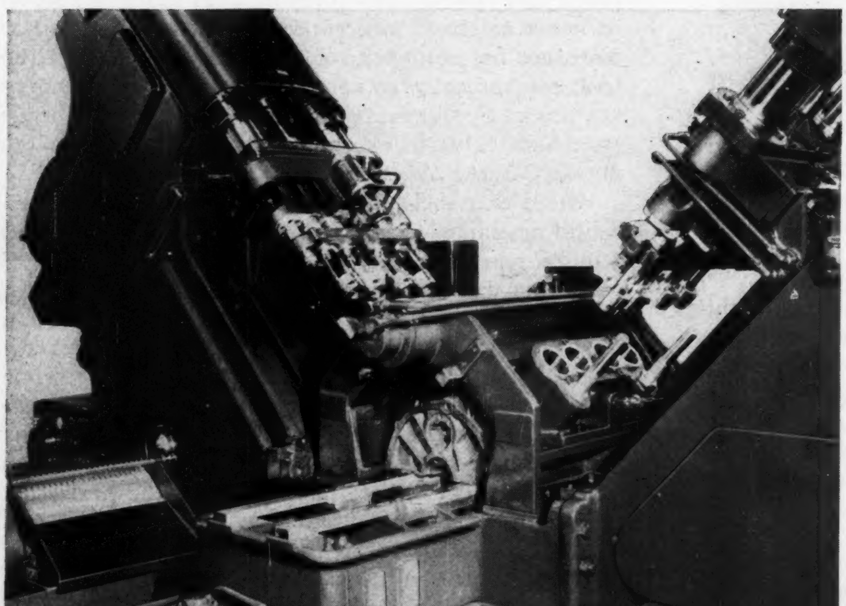


Fig. 7 — Left — Hydraulically operated special duplex automatic engine-block honer for mass production

triple-roll machines, *Fig.* 9, can be used to rough and finish lap parts with one handling. Either manual or automatic feeds can be used, depending upon production requirements, for lapping cylindrical, tapered or shouldered parts from 0.030-inch to 10 inches in diameter, *Fig.* 2. Contoured parts require special rolls.

Using the through-feed centerless principle and a solid bonded-abrasive wheel much the same as in centerless grinding, continuous mechanical lapping is obtained. On these machines both lapping and regulating wheels are 14 inches in diameter by 22 inches in face width. Regular or grind-lapping is usually done with a 180-grain wheel and the finest lapping with a 500-grain. Where through feeding is used, only cylindrical parts can be handled. Shouldered parts can be lapped by in-feed but at lower production rates. Short parts, ¼-inch to 6-inch diameters by up to 15 inches in length, can be handled and long parts from ½ to 3 inches in diameter up to 15 feet in length.

Following a relatively smooth grind of less than 20 microinches, lapping with abrasive coated paper will produce surface improvement. However, little correction of surface irregularities or dimensional inaccuracies can be made. A bright polished finish can be effected on a variety of parts with contours which defy the use of previously mentioned methods. Internal contours of ball races, etc., are often lapped by this method and the part is chucked on a rotating mandrel, the lap being manipulated by hand.

Design: Honing, in general, should not be considered for diameters under ¼-inch. Maximum diameters feasible have been outlined previously in relation to each type machine. In small-diameter parts, length of bore is limited to approximately 20 times the diameter. Bores over ⅝-inch, however, may be honed to any practicable length. The primary limiting factor in the length of large-diameter parts is the machine tooling and handling equipment. Work in which the length of hole is less than the diameter usually requires piloting and such parts are often honed in multiple, *Fig.* 10.

For most economical honing, the roughing operation—drilling, boring, reaming, etc.—should remove the bulk of the stock leaving only sufficient material to clean up and correct inaccuracies. As a general rule, about twice as much stock should be left for honing as there is error present. For instance, slush pump liners from 60 to 64 Rockwell C showing 0.040-inch to 0.050-inch out-of-roundness from heat treating, have 0.080-inch of stock removed in honing to size. Thus economical stock removal can range from 0.002-inch to 0.090-inch on diameters over 2 inches while below 2 inches the range is from 0.005-inch to 0.020-inch. On parts processed for finish only or where the cost of accuracy on the preceding operation is low, the honing allowance can be from 0.001-inch to 0.004-inch to minimize honing time. However, if close tolerances on the preliminary operation are expensive, it will be cheaper to remove from 0.010 to 0.030-inch in honing. As an example, long tubes as received from the mill can have 0.040 to 0.075-inch of stock honed out faster than they can be bored close to size and finish honed. Again, on cast

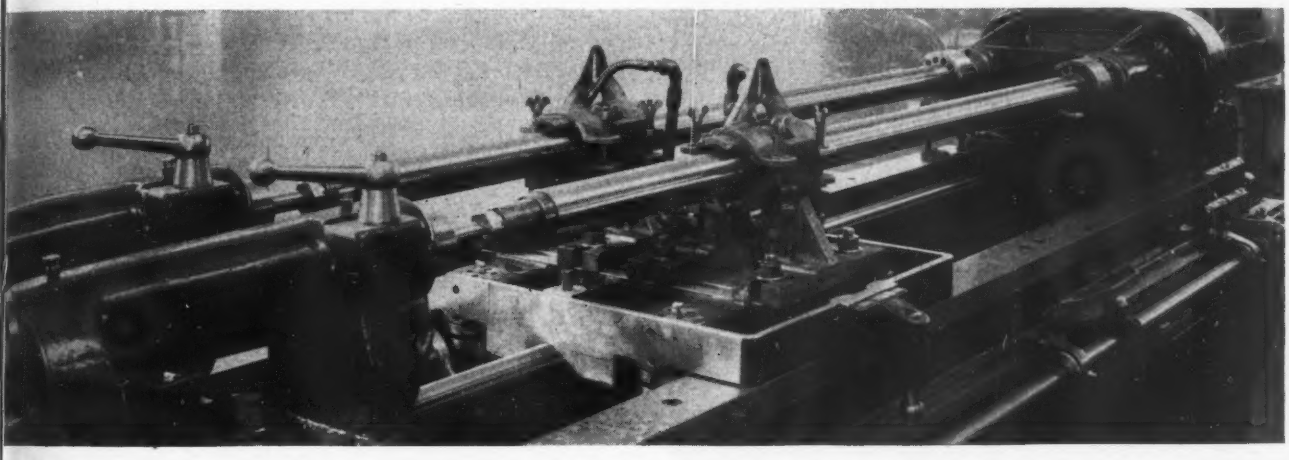


Fig. 8—Above—Barnesdril No. 5-L external straight-line lapper finishing 3.350-inch recoil piston rods 57 inches long

Fig. 9—Below—Dual-roll centerless lapping machine for both rough and finish lapping operations

or forged cylinders where diameter tolerance is fairly liberal it has been found advantageous to bore with a round-nose tool at a feed of about 0.50-inch so as to leave high ridges of about 0.010-inch because these can be honed down to a geometrically true bore surface with extreme rapidity. For very fine finish, though, rough and finish operations are necessary if stock removal is great. Precise bores such as for motor blocks should be fine bored prior to honing, leaving 0.003 to 0.006-inch of stock to straighten and clean up the bore.

Many complications such as bosses, struts, ports, slots at the end of a bore, oil grooves, keyways, shoulders, blind bores, etc., are unavoidable in design and serve to prevent the accomplishment of closest accuracy in honing but, as a rule, can be handled sat-

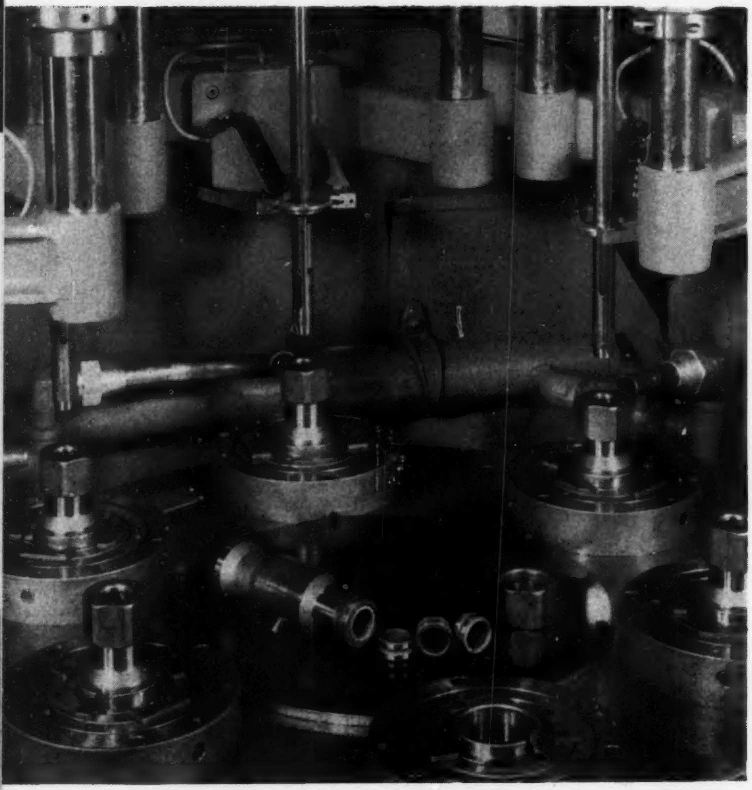


Fig. 10—Above—Three-spindle Hydrohoner adapted to hone ball-bearing cone followers progressively. Parts are mounted 10 to a shuttle

Fig. 11—Below—Motor armature spider with stepped, honed bores showing honing clearance at blind end

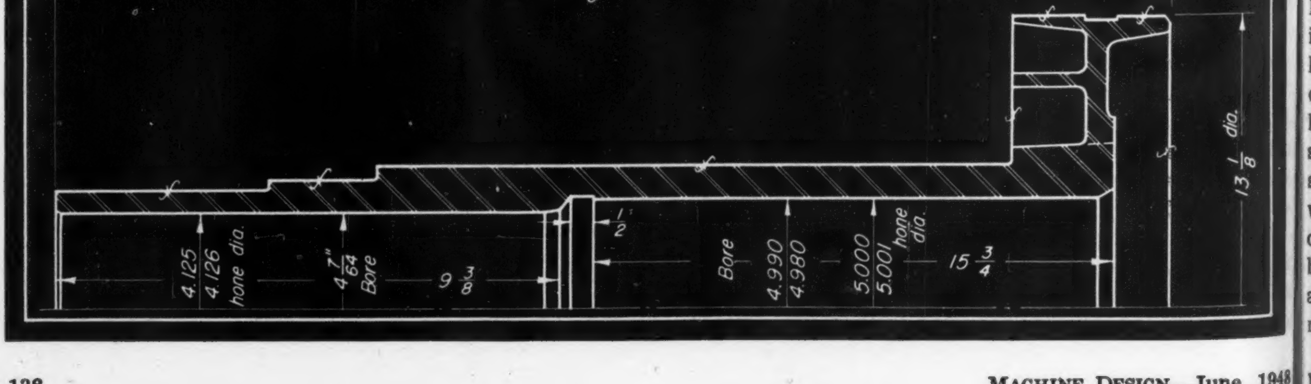
isfactorily. With blind-end bores, as in grinding, it is good practice to provide a slight undercut or recess at the bottom at least a few thousandths larger than the finished bore, *Fig.* 11, and about 1/8 to 1/4-inch in length. On interrupted surfaces, alignment will be maintained and bore will be straight but some overcutting will be present at the edges of the reliefs. On relatively soft parts containing keyways, oil grooves, etc., honing usually is done prior to cutting the keyways or oil grooves whereas, on hardened parts, the job can be honed after these features have been added by using a special tool arranged so that the stone carriers ride over the relieved portions.

For lapped parts, restrictions on size and shape have been generally outlined in the preceding discussion and practical design must naturally observe such limitations. For most efficient lapping in production, a minimum amount of stock should be left for finishing. Stock allowance should never be more than 0.0005-inch, preferably not over 0.0002-inch for rough lapping or 0.0001-inch for finish lapping from a rough-lapped surface. The preliminary processing operation should either be grinding or honing to provide the geometrical and orientation accuracy desired.

Materials: All ferrous materials as well as many nonferrous materials such as bronze, brass, and silver can be honed satisfactorily. Also nonmetallics such as glass and certain ceramics can also be processed. Quality of honed finish obtainable with the softer materials is somewhat inferior to that possible with the harder ones.

Lapping with loose abrasives as a rule is somewhat unsatisfactory for finishing the relatively softer materials. The tendency is for the abrasive to charge or embed itself in the surface of the part being lapped. Also, there is a tendency to remove more of the softer portions of a surface than the harder with materials such as cast iron. This is also true with abrasive-coated paper lapping. With bonded-abrasive lapping, however, these tendencies are not present. For best results with lapping, materials in the harder ranges should be specified.

Tolerances: Reproducible, uniform accuracy in most modern honing applications on diameters over 4 inches can be held within 0.0005 to 0.001-inch total variation for roundness and straightness; on diameters from 4 inches down to 1-inch this can be 0.0003 to 0.0005-inch; and on bores below 1-inch it is usual-



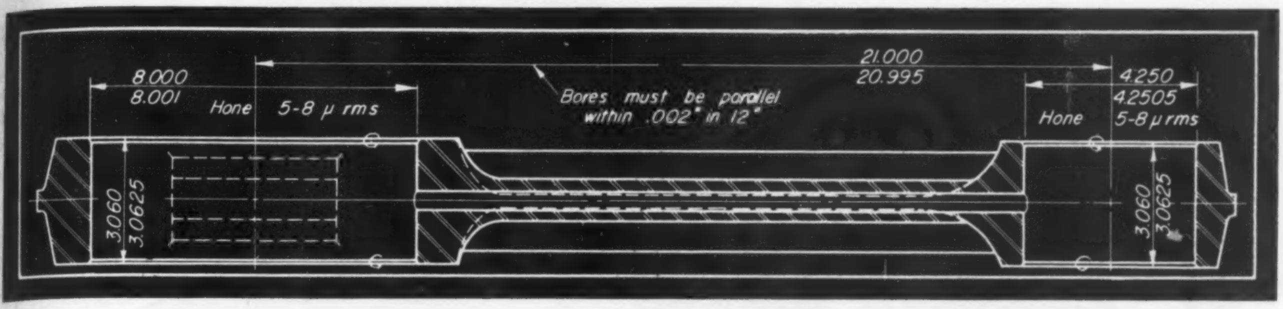


Fig. 12—Above—Large connecting rod showing honing tolerances held in production, and surface finish specified

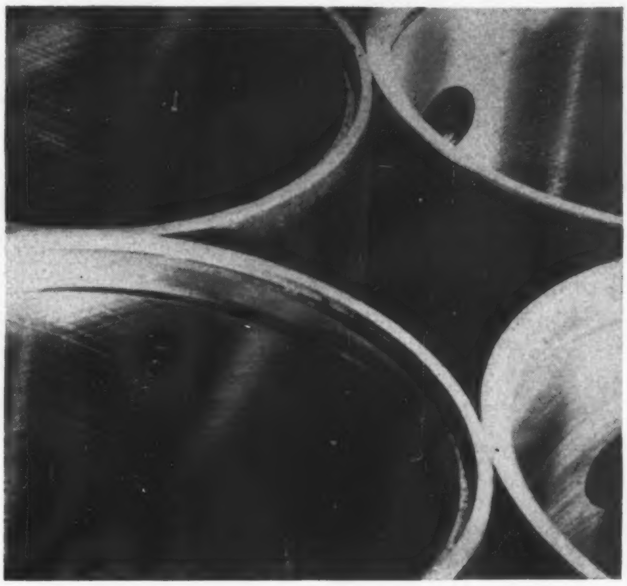
Fig. 13—Below—Group of honed hydraulic cylinders showing typical scratch pattern

ly within 0.0001-inch to 0.0003-inch, *Fig.* 12. In production runs on Microhoning machines fitted with aumatic Microsizing equipment, diameters under 2 inches can be held to less than 0.0003-inch total variation and over 2 inches to less than 0.0005-inch. In general, tolerances of plus or minus 0.0001-inch to 0.00025-inch are commonly attained and on certain jobs where the maximum in accuracy is necessary, diameters can be held within a total variation of 0.000025-inch but, at some sacrifice in production.

Parts with ports, interruptions or unequal surfaces are difficult to hold to close tolerances, accuracy usually being about 0.001-inch generally although, on occasion, a tolerance as close as 0.0003-inch has been held. Designs of this nature and blind holes without relief should be avoided where tolerances must be held closer than 0.0005-inch.

Straight-line honed or lapped piston rods and similar parts can be held to like tolerances, 8-foot rods, for example, being finished to within 0.0001 to 0.0002-inch for roundness and taper, *Fig.* 6. In lapping small parts by the centerless method size accuracy can be held to a total variation of 0.00005-inch on diameter and 0.000025-inch on straightness. Preceding lapping the parts should be ground to a good commercial finish, sized within about 0.00025-inch, and held as round as desired in the finished job. Lapgrind, a finish between lapping and grinding, is obtained in one operation with a maximum stock removal of 0.0005-inch and surface finish of 4 to 6 microinches. After the lap-grind operation, surface finish may be improved to 2 to 3 microinches with a maximum stock removal of 0.0001-inch using the 500-grit wheel. Finest finish of about 2 microinches can be obtained in a third operation.

As mentioned previously, the surface quality obtainable in honing can be held as required by the particular design application with a few limitations as to materials. In hard steel the surface finish attainable will range from 20 to as low as 1 microinch. In bearings with a hardness of 60 Rockwell C, removing from 0.006 to 0.014-inch of stock, finish may be held as low as 2 microinches in production. This accuracy requires a two or three-step honing operation, however, since the same abrasive that will remove stock will not produce the finest finish. In lapping, surface finishes under 2 microinches can be attained where necessary and measurements show a low limit of about 0.5-microinch. In cast iron, soft steel or bronze, honed finish obtainable may run from 80 to about 3 microinches, 5 to 10 being average. Fineness of finish with cast iron is limited mainly by the



grain structure of the material. With aluminum, a finish of about 15 microinches can be produced.

Judicious selection of surface finish for honing will afford considerable economy in production and also provide the most desirable surface functionally. For accurate pressure-lubricated bearings, fluid seals, etc., the most desirable surface finish is the smoothest possible, say from 1 to 5 microinches. Cylinder walls or other surfaces which are regularly wiped by another part will require quicker, faster wetting by a lubricant, and perhaps good heat dissipation in addition, which is afforded best by somewhat rougher surfaces, say 5 to 30 or more microinches, with the most desirable scratch pattern. A cylinder using leather or O-ring packings would indicate a finish from 10 to 15 microinches with a regular cross-hatch pattern, *Fig.* 13. Again, where a codirectional finish or surface with a minimum of pattern is indicated, lapping can be employed to advantage.

Collaboration of the following organizations in the preparation of this article is acknowledged with much appreciation:

Barnes Drill Co. (*Figs.* 4, 6, 7, 8, and 13) . . Rockford, Ill.
Cincinnati Grinders Inc. . . . . Cincinnati, Ohio
C. Allen Fulmer Co. (*Figs.* 5, 11, and 12) Cincinnati, Ohio
Micromatic Hone Corp. (*Figs.* 1, 3, 10) . . . . Detroit, Mich.
Size Control Co. Div. American Gage & Machine Co.
(*Figs.* 2, and 9) . . . . Chicago, Ill.
Sunnen Products Co. . . . . St. Louis, Mo.

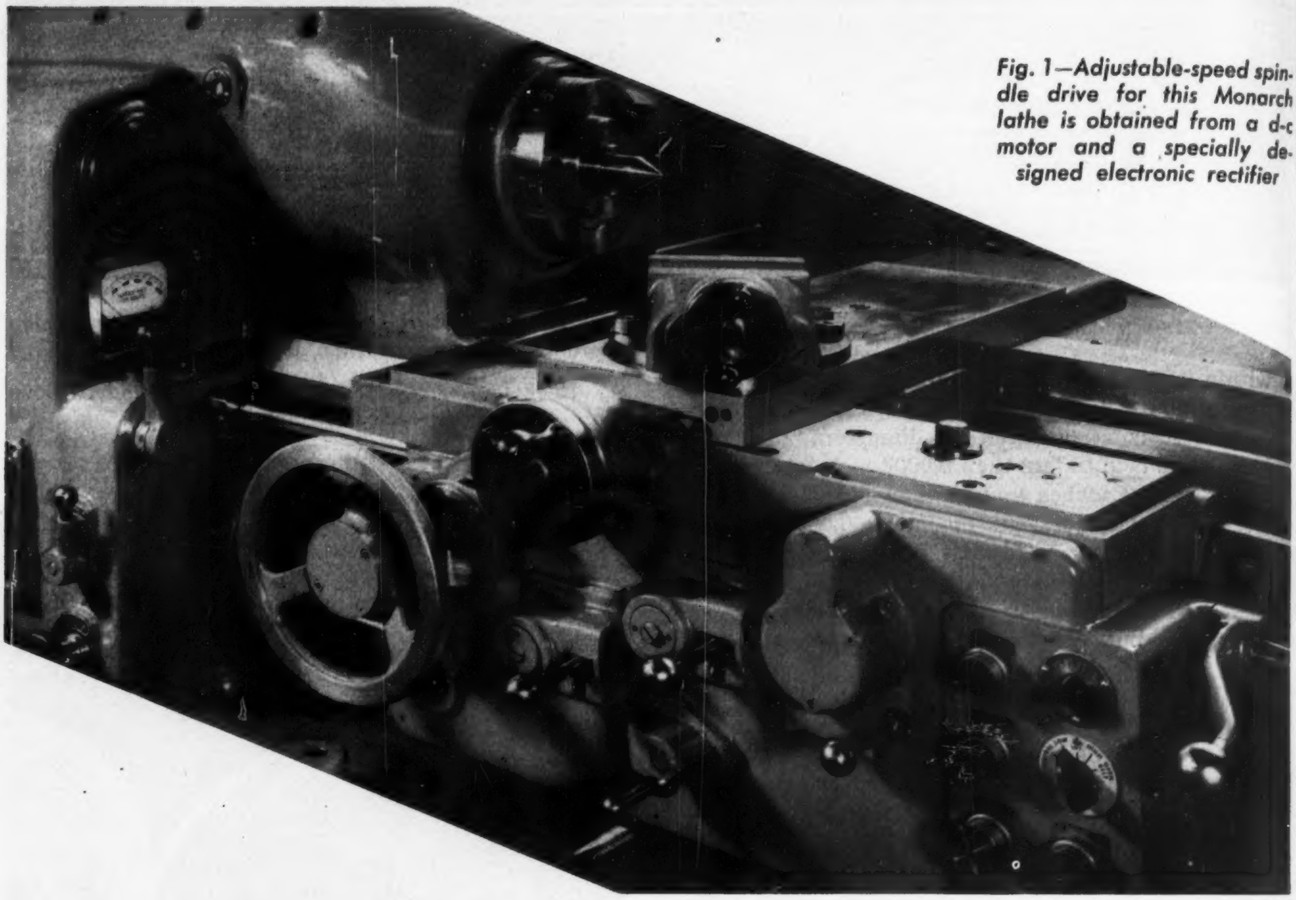


Fig. 1—Adjustable-speed spindle drive for this Monarch lathe is obtained from a d-c motor and a specially designed electronic rectifier

Choosing a D-C Power Source

By L. W. Herchenroeder

Industry Engineering Department
Westinghouse Electric Corp.
East Pittsburgh, Pa.

Proper choice of conversion equipment is not always apparent when direct-current electric power is required for machine drives and components. The three commonly used types are discussed in a comparative manner in this abstract of the author's paper for the Machine Tool Forum recently held at Westinghouse Electric Corp. Buffalo plant

MOTORS, solenoids, magnetic chucks, clutches, and brakes often require direct-current power to perform their specified tasks. Because electric power is usually provided in the form of alternating current, some form of conversion equipment is required. Choosing the best type of conversion unit for a particular application involves careful consideration of many factors such as original cost, space required, maintenance involved, and voltage regulation. For adjustable-speed d-c drives, additional factors of speed range, speed regulation and motor size are involved.

Three forms of conversion equipment are normally used for machines. They are the metallic rectifier which may be of the copper-oxide or selenium type, the electronic rectifier and the motor-generator set. Each has certain advantages and sometimes there

is some confusion as to the proper one to use for a given application. The problem may be simplified somewhat by breaking it up into two parts, the first concerning a general source of direct-current power for solenoids, etc., and the second involving d-c adjustable-speed drives, *Fig.* 1.

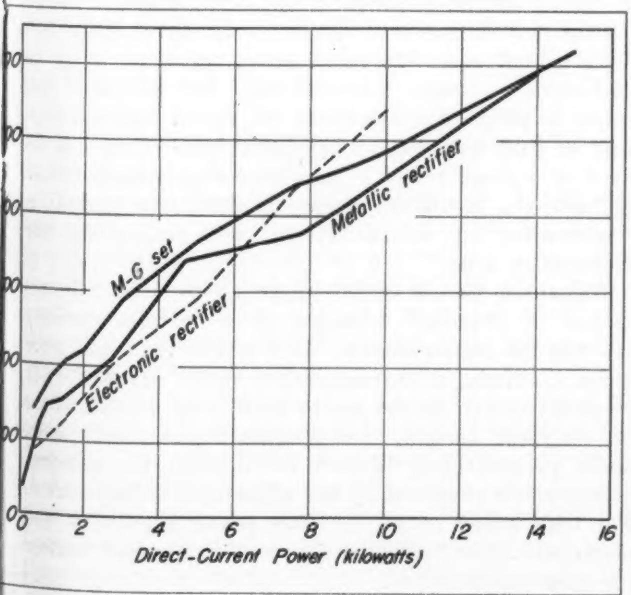
First concern, then, is a simple source of d-c power at constant voltage. *Fig.* 2 shows comparative prices of the three forms of rectifiers, based on 230-volt d-c power supply and plotted against kw output. The metallic rectifier is lowest below ½-kw and between 6½ to 15 kw. The electronic rectifier is lowest from ½ to 6½ kw. Above 15 kw the motor-generator set has the advantage. It should be noted that these comparisons are only for 230-volt supply. For other voltages the following factors affect the price of equipment.

Cost of the transformer of an electronic rectifier is relatively independent of the voltage output, that of the tubes is determined by the current required. Assuming a certain kw output, if the d-c voltage is halved, tubes of twice the current rating will be required. Thus, for a given kw output, the electronic rectifier becomes more expensive as the output voltage is reduced.

Motor-generator sets are the same in price for 125 or 250 volts in the kw ratings shown in *Fig.* 2. Below 125 volts the higher current required will increase the cost of the commutator and armature, resulting in increased price per kw winding for the motor-generator set.

Metallic rectifiers, however, are flexible with respect to output voltage. The transformer can, of course, be arranged to give any reasonable output voltage. By suitable choice of plates or disks and circuits, a wide range of output voltages can be accommodated. Thus the price of the metallic rectifier is approximately independent of the output voltage.

Fig. 2—Comparative costs of motor-generator sets, electronic rectifiers and metallic rectifiers for supplying 230-volt direct-current power



Installation costs of metallic and electronic rectifiers are approximately the same because they are both static devices and require no special mountings. Installation cost of the motor-generator set is higher since it is a rotating device and must be mounted on a firm foundation.

From the standpoint of maintenance the metallic rectifier has a distinct advantage. The aging taps on the transformer may require adjustments for several years but, after that, no special maintenance is required. Electronic rectifiers and motor-generator sets are about equal from a maintenance standpoint. One requires replacement of tubes and the other brush and commutator maintenance. Bearing maintenance is becoming a minor problem with the improvements in bearings and the use of sealed ball bearings in the smaller ratings. On the basis of vibration the metallic and electronic rectifiers are equal while the motor-generator is less favorable because of its rotating parts.

Voltage regulation of electronic and metallic rectifiers is about the same being approximately 10 per cent for a self-cooled and about 15 per cent for a fan-cooled selenium rectifier. Regulation of copper-oxide rectifiers is somewhat higher being approximately 30 per cent for a self-cooled and 15 to 20 per cent for fan-cooled unit. Regulation of the motor-generator set is superior; ±3 per cent being obtainable by flat compounding at no price increase.

TABLE I

General Comparison of D-C Power Supplies

	Metallic Rectifier	Electronic Rectifier	Motor-Generator Set
Price	Lowest except for cases noted at right	Lowest for 230/volts ½ to 6 kw	Lowest above 15 kw
Space Requirement	Smallest below 250 volts	Smallest above 5 kw	Largest
Installation Cost	1	1	2
Maintenance	1	2	2
Vibration	1	1	2
Voltage Regulation	2	2	1
Ease of Voltage Adjustment	2	2	1

In the above tabulations 1 is the most favorable.

Voltage adjustment is easily accomplished on the motor-generator set by means of a generator field rheostat. However, transformer taps must be provided to adjust the voltage of the metallic and electronic rectifiers.

Space requirements are, in general, greater for the motor-generator set than for either metallic or electronic rectifiers. At 250 volts the metallic rectifier requires the least space for one kw and below. The electronic rectifier is smallest above 6 kw. At voltages below 250 the metallic rectifier is generally smaller. The general considerations discussed for the three types of conversion equipment are listed comparatively in TABLE I.

Adjustable-speed drives represent an important

field for d-c power supplies. In line with the foregoing discussion, three forms will be considered; namely, the metallic-rectifier (Selenium) drive, electronic (Mototrol) drive, and the adjustable-voltage (AV) drive. In its simplest form the Selenium drive consists of a transformer, a selenium rectifier, an adjustable-speed d-c motor, an a-c linestarter, and a motor-field rheostat. Speed control is obtained entirely by adjusting the field of the motor. This drive is, therefore, best suited for constant-horsepower loads. Normally, speed ranges up to 4 to 1 can be obtained.

The Mototrol uses grid-controlled thyratrons to supply adjustable voltage to the armature of a d-c motor. Thyratrons may also be used to supply the field of the motor when part of the speed range is to be obtained by motor-field control. Standard speed ranges at constant torque by armature-voltage control up to 40 to 1 may be had.

The AV drive is a conventional drive using a motor-generator set to supply adjustable voltage to the armature of a d-c motor. The standard drive provides a speed range up to 8 to 1 by armature voltage control and up to 2 to 1 by motor field control.

TABLE II compares these drives in several ways. The electronic drive is the most expensive for both constant-torque and constant-horsepower drives. The

TABLE II

D-C Adjustable-Speed Drives

		Type of Drive		
		Metallic Rectifier	Electronic Rectifier	Adjustable Voltage
Price	Constant Torque	2	3	1
	Constant HP	1	2	1
Speed Range		4 to 1	40 to 1	16 to 1
Speed Regulation		3	1	2
Positive Slowdown		No	No	Yes
Smoothness of Acceleration		3	1	2
Vibration	Power Supply	1	1	2
	Motor	2	3	1
Motor Size	Constant Torque	3	2	1
	Constant HP	1	2	1
Rheostat Size		2	1	2
Maintenance		1	2	2
Installation Cost		1	1	2

In the above tabulations 1 is the most favorable.

adjustable-voltage drive is least expensive for constant-torque drives. The metallic-rectifier and adjustable-voltage drives are approximately equal in cost for constant-horsepower drives.

Speed regulation of the electronic drive is the best with the adjustable-voltage second and the metallic rectifier third. The adjustable-voltage drive provides positive slowdown when changing the speed to a lower value in the same direction. This is of importance in cycle types of operation. With respect to smoothness of motor acceleration, the electronic drive is best, followed by the adjustable-voltage and metallic-rectifier drives.

To compare the drives on the basis of vibration, the power supply and control should be considered separately from the motor. The metallic rectifier and electronic power supplies are most favorable from the standpoint of vibration because they are static devices. Vibration of the adjustable-voltage drive motor is most favorable and the electronic drive motor least favorable. The metallic-rectifier and electronic drive motors have increased vibration because of the pulsating nature of the armature current.

Comparison of Space Requirements

The adjustable-voltage drive has an advantage in the size of the d-c motor for constant-torque drives because a standard frame is used. The metallic-rectifier drive requires a larger motor because the base speed of the motor is at the lower end of the speed range. The electronic drive uses the standard frame size in some cases. However, it is generally necessary to use the next larger frame size because of the added losses caused by the pulsating nature of the armature current. For constant-horsepower drives both the adjustable-voltage and metallic rectifier drives use the standard frame size. The electronic drive requires an increase of one and sometimes two frame sizes because of the greater difficulty experienced in commutating the pulsating armature current.

The power supply and control space requirements are not as consistent as the motor size. The metallic-rectifier drive is the smallest except at $1\frac{1}{2}$ and 2 hp where the adjustable-voltage drive has the advantage. The electronic drive is the largest up to 5 hp where it equals the adjustable-voltage drive. Above 5 hp the latter is the largest. The electronic and metallic-rectifier drives are approximately the same size above $7\frac{1}{2}$ hp. The former has a definite advantage in the size of the speed-control rheostat which is mounted in the pushbutton station. Both the metallic-rectifier and adjustable-voltage drives require conventional motor or generator-field rheostats.

Selection of the best drive for an application follows no set rule. In some cases the drive may be picked on a single characteristic. For example, the space available for mounting the motor may be limited so that only the adjustable-voltage drive can be used or a small rheostat may be desired which would indicate the use of an electronic drive. In general, a combination of characteristics will determine the drive to be used.

Assuming that a speed range up to 4 to 1 is required at constant horsepower, a metallic-rectifier drive is the logical choice. It is low in price and provides a simple, maintenance-free drive. However, if constant-torque drives up to 8 to 1 or combinations of constant torque and constant horsepower over speed ranges up to 16 to 1 are desired, the requirements are best served by the adjustable-voltage drive. For wide speed ranges or close speed regulation, the electronic drive furnishes the most economical answer for most applications.

Lifetime Bearing in New Meter

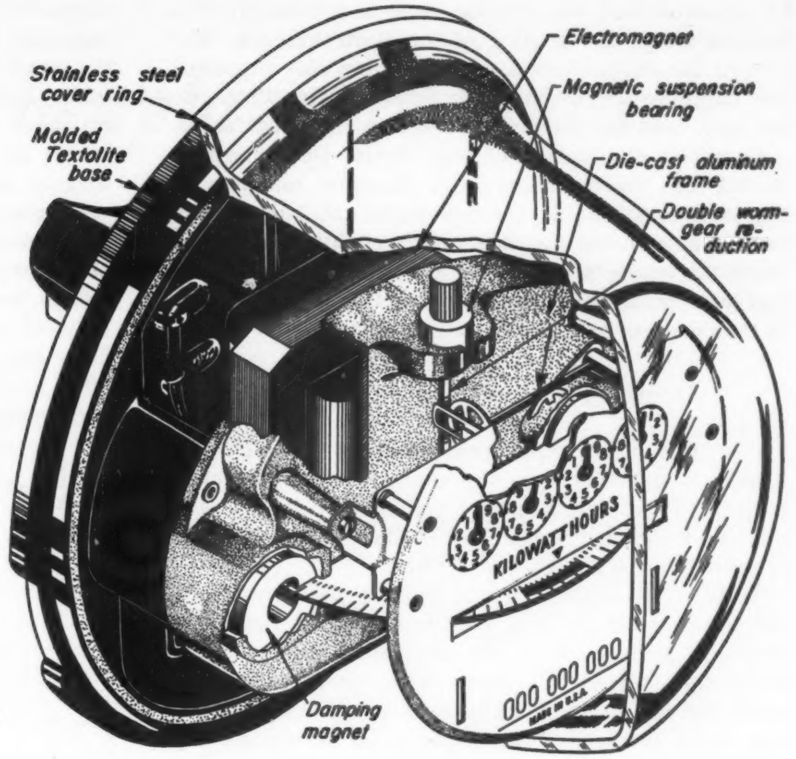


Fig. 1—Cutaway view of new watthour meter shows design features such as magnetic-suspension bearing and cast-in damping magnets

SOMETHING new has been added in the field of mechanism design. Its implications reach into the design departments of machine building companies throughout the country. That something new is a magnetic-suspension bearing which engineers of General Electric have built into the recently announced Model 1-50 watthour meter, *Fig.* 1.

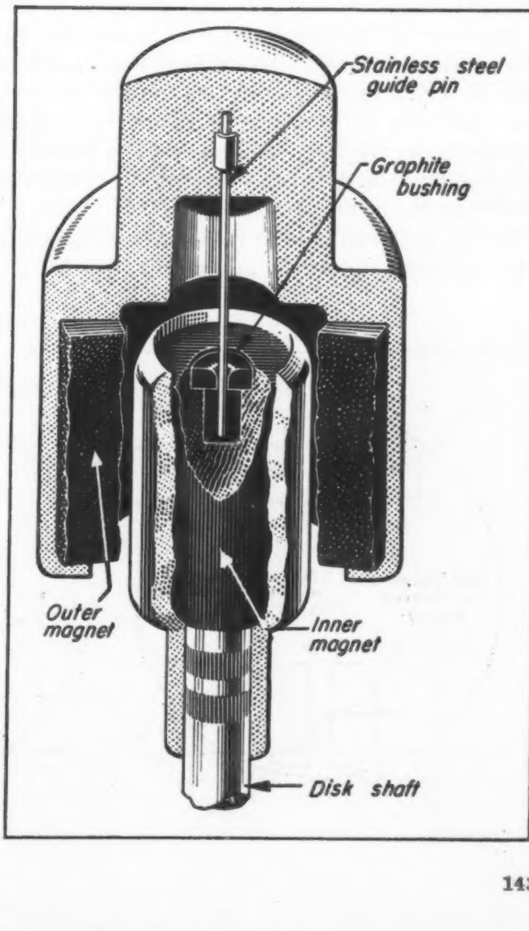
In the G-E meter, the new bearing is used to suspend or "float" in a magnetic field the electromagnetically driven disk which measures electric energy. As the cutaway view of *Fig.* 2 shows, two cylindrical permanent magnets of the high-coercive and machinable material Cunico are placed one within the other. The outer magnet is fixed to the meter frame and the inner magnet is attached to the upper end of the disk shaft. These concentric magnets are magnetized axially with opposite polarities. The resulting field supports the disk assembly at a definite, small downward displacement.

To maintain bearing alignment, a stainless steel guide pin is provided at each end of the shaft. Graphite bushings, *Figs.* 2 and 3, run on these guide pins without lubrication. Thus, the only possible cause of mechanical friction and wear is the presence of side-thrust forces.

In conventional meters employing jeweled bearings, bearing stress due to disk weight is about 200,000 psi. In the new meter, bearing stress due to disk weight is completely eliminated. Moreover, the torque-to-weight ratio, long accepted as being in the order of 3 or 4 to 1, has been increased to infinity. (This comparison in both cases ignores the secondary effects of side thrust.)

Along with the use of magnetic suspension, the meter structure has been arranged to keep side-thrust forces low. These forces arise from the action of the electromagnet and the damping magnet on the meter disk. In the conventional meter, *Fig. 4a,* the electromagnet is mounted behind the frame and disk shaft, and the damping magnet is located at the front of the meter. When a torque is created in the disk

Fig. 2—Below—Disk shaft is suspended by magnetic field of bearing; axial alignment maintained by guide pin running in graphite bushing



by a power load, the driving force is equivalent to a side thrust at the location of the electromagnet. Motion of the disk causes a corresponding side thrust at the damping-magnet position. Total side thrust on the disk bearing is equal to the sum of these forces.

Complete elimination of side thrust would require having the electromagnet and damping magnets in the same location. In the new meter the large reduction in side thrust has been achieved by locating the damping magnets closer to the electromagnet than has been heretofore possible, *Fig.* 4*b*. Side thrust is in the order of 100 psi at maximum load.

Damping Magnets Cast Into Frame

The two small C-shaped damping magnets, of Alnico 5, are cast into the die-cast aluminum-alloy frame. Thus, the magnets are surrounded by aluminum, which enhances the excellent surge-resistant properties of the magnet material.

In the 1-50 meter, current coils of the electromagnet are formed of bare copper wire. At assembly, they are located with the electromagnet core in a mold that aligns all parts with proper spacings. Butyl rubber is then introduced to the closed mold and cured in place. The result is an accurately and securely located current coil with the rubber providing turn, coil and ground insulation. This is in contrast to the usual practice of using coil wire insulated with tape, enamel or Formex.

For greater insulation strength, reliability and secure positioning, the layer-wound potential coil, consisting of many turns of fine wire, is similarly molded to the electromagnet core. The molding material in this core is a polyethylene plastic of high dielectric strength and low moisture absorption.

Register of the new meter is furnished as either the pointer type, as shown in *Fig.* 1, or the cyclometer type in which the numerals are located on the peripheral surfaces of vertically mounted cylinders. The pointer-type register employs a time-proven double-worm-gear reduction and bearings of stainless-steel pins running in aluminum.

In the cyclometer-type register, partially-turned or half-obscured numerals are eliminated by a unique magnetic storage and release effect. Two Cunife magnets, one fixed to the bearing plate and one to the shaft of the first cylinder, repel and attract each other during alternating halves of one complete revolution of the cylinder. The coercive force of Cunife snaps the cylinders into position when the moving magnet goes over dead magnetic center.

Corrosion is effectively eliminated in the 1-50 by the combination of a molded Textolite base and a stainless steel cover ring, *Fig.* 1. Another important design feature of the meter is the controlled air gap between the current-coil leads and the ground pins. This gap, which has a break-down level of between 4000 and 5000 volts, directs overvoltage away from the electromagnet to ground.

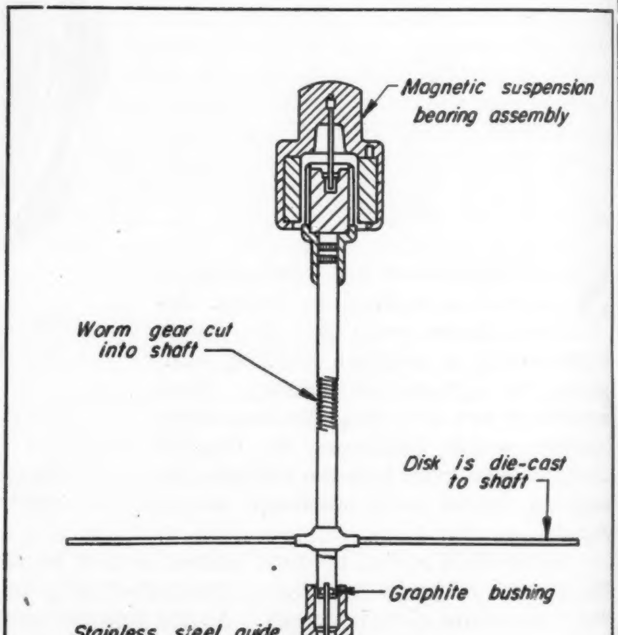


Fig. 3 — Above — Cross section through disk, shaft and bearing assembly. Stainless steel pins running in graphite bushings at top and bottom require no lubrication

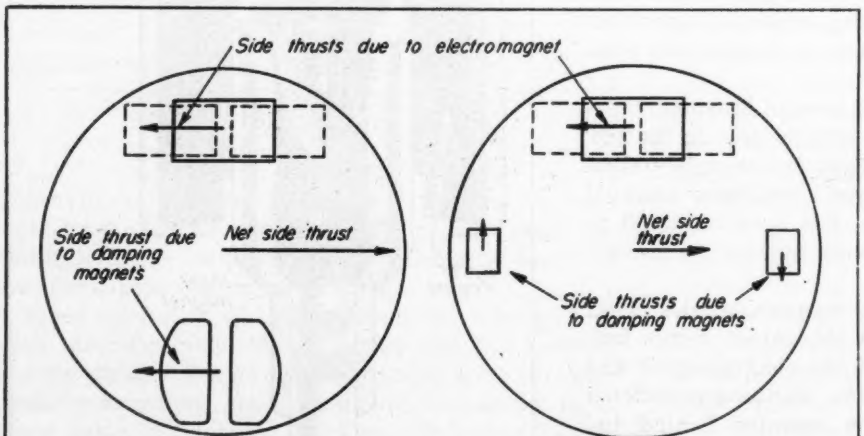
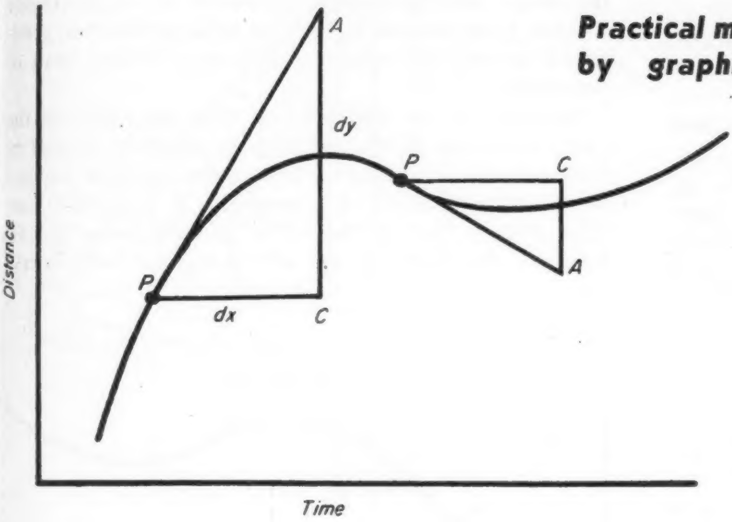


Fig. 4—Left—Schematic top views of conventional meter (a) and new 1-50 meter (b) show how new positioning of damping magnets effectively reduces side thrust on disk shaft bearings

Analyzing Graphical Records



Practical methods of determining rates of change by graphical and numerical differentiation

By Charles E. Balleisen
Associate Professor
of Mechanical Engineering
Purdue University
Lafayette, Ind.

SEVERAL methods exist for securing records of the motion of a machine part as a function of time. Such curves are extremely useful in investigating the timing of the various parts of mechanisms and often reveal previously unsuspected vibrations, bounces, or other anomalies not predicted by the designer.[1] Whereas the knowledge that these variations from theory exist is of great value, it is even more important to know the magnitudes of the forces induced by these changes of motion.[2] If the forces are sufficiently great, it may be necessary to redesign the product in order to avoid premature failures.

Analysis of the records is not often carried to this desirable extent, because of the labor involved in determining acceleration forces from the time-displacement records. It is well known that the acceleration is equal to the second derivative of this curve, yet considerable practical difficulty may be encountered in performing this operation. A few types of instruments to produce mechanically successive derivatives of a curve have been developed, but they are expensive and difficult to procure. As they depend for their accuracy upon an adjustment of the index to a direction parallel to the slope of the curve, this accuracy is largely a reflection of the skill of the operator.

Common methods of "graphical differentiation" are easy to carry out, but do not consistently give reliable results. Unless extremely small intervals are used, the assumptions underlying the method are liable to introduce appreciable error. Further, the second derivative can only be obtained by performing two successive differentiations. The curve of the first derivative must be obtained first, and subsequent smoothing of this curve introduces personal

[1] References are listed at end of article.

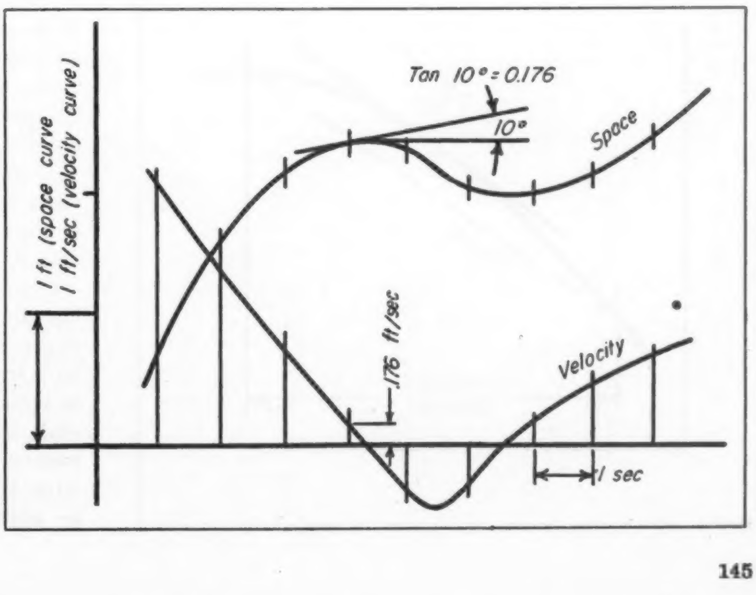


Fig. 1—Top—Time-distance curve, showing relation between slope of tangent PA and the rate of change of the curve at two points

Fig. 2—Right—Graphical differentiation is performed by measuring the angles of the tangents at many points

X	Y	a	b	c	d
x_1	y_1				
		a_1			
x_2	y_2		b_1		
		a_2		c_1	
x_3	y_3		b_2		d_1
		a_3		c_2	
x_4	y_4		b_3		d_2
		..		..	
..	..		..		..
		..		..	
..	..		..		..

errors which render the second derivative uncertain.

The method of Successive Differences gives a numerical answer with a minimum of calculation. A graphical construction, with its subsequent inaccuracies, is not required. The only limitation placed on the original data is that the curve must be scaled or "read" at points separated by equal values of the independent variable. As these data are secured by measurements from a continuous performance record, this requirement is easily met.

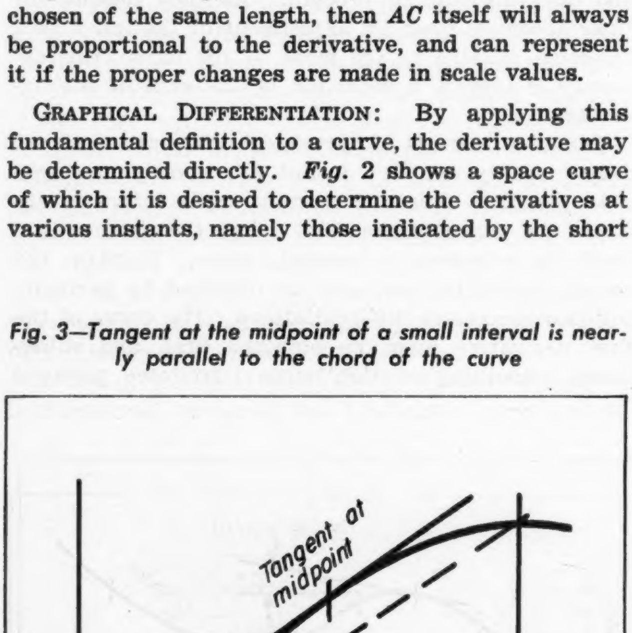
With the foregoing introduction to the various types of methods for securing successive differentiation, each of them will now be discussed in turn.

STATEMENT OF THE PROBLEM: From a curve such as *Fig.* 1, the derivative at any selected point is equal to the tangent of the slope of the curve at that same point. Stated mathematically, the derivative of $f(t)$ at point P is $dy/dx = CA/PC$. If PC is always chosen of the same length, then AC itself will always be proportional to the derivative, and can represent it if the proper changes are made in scale values.

GRAPHICAL DIFFERENTIATION: By applying this fundamental definition to a curve, the derivative may be determined directly. *Fig.* 2 shows a space curve of which it is desired to determine the derivatives at various instants, namely those indicated by the short vertical lines. Short lengths of tangents are drawn, their angles are measured, and the tangent values placed in corresponding positions as shown by the lower curve. The difficult part of this construction is to determine the actual tangent. There does not exist any general method of determining this direction except by visual judgment. However, having determined the direction of the tangent, the value of the slope may be readily measured by a protractor (which gives *arctan* dy/dx) or by a protractor graduated directly in values of the slope rather than of the angle.

Because of the difficulty of thus determining the exact direction of the tangent, it is often desired to approximate this value by taking the value of a chord of the curve instead of a tangent. It is readily seen from *Fig.* 3 that if the curve is continuous in this interval, the slope of the chord will be very nearly

Fig. 3—Tangent at the midpoint of a small interval is nearly parallel to the chord of the curve



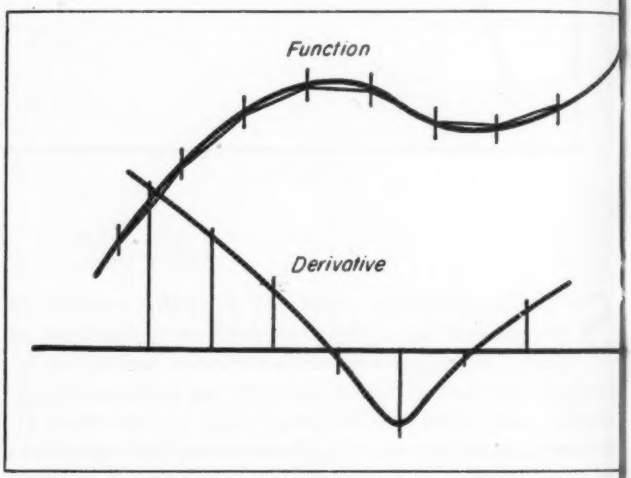


Fig. 4—Derivative curve is obtained by measurement of the slopes of the chords of small arcs

that of the tangent at the midpoint of the interval. If this approximation is accepted as satisfactory, then the values of the slope of the chord may be set down at the midpoints of the successive intervals and a curve of the derivative secured, *Fig.* 4. If a second or further derivative is to be taken from this curve, it is evident that any errors introduced by this approximation will be carried over into the subsequent steps. If, however, the intervals are kept sufficiently small, these errors may be kept below other, accidental, errors of construction.

If a continuous differentiation is required rather than a construction prepared from point to point, it is necessary to employ a differentiating instrument, *Fig.* 5.

Operation of such a machine is quite simple. If the index-line c is kept parallel to the y-function curve at all times, point e or a corresponding point will trace out the dy/dx curve as the differentiator is rolled across the paper. In actual operation, several difficulties present themselves. First, it is necessary to align the instrument absolutely parallel with the x-axis of the curve. Such alignment must be maintained, as any derangement will result in a

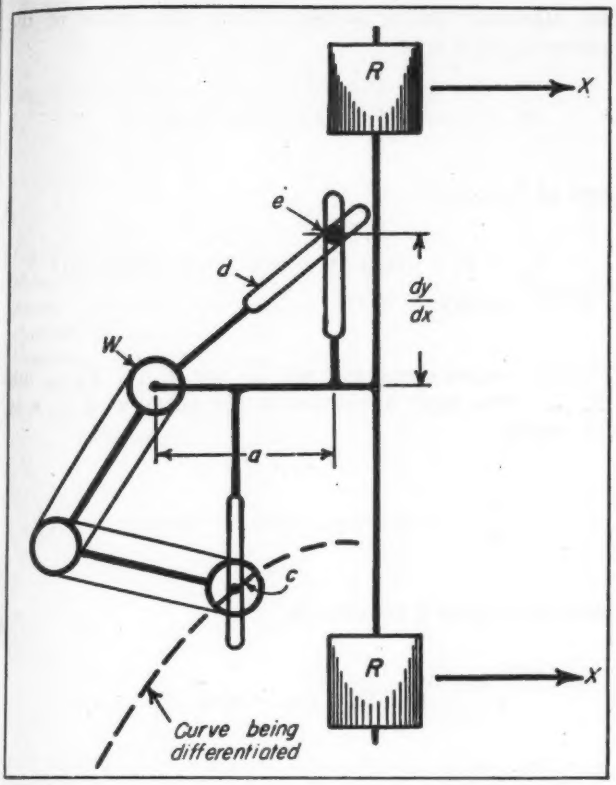


Fig. 5—Mechanical differentiator computes and draws velocity curve if index wire is kept parallel to record

wrong interpretation of the readings. A second difficulty occurs in setting the index wire c parallel to the tangent of the curve. This is the same difficulty that is encountered in the graphical method previously described. It is possible that it could in some measure be overcome by attaching an additional drive to the differentiator so that the index would follow the curve as the instrument as a whole progressed across the paper. In this fashion, any deviation from the proper setting would soon be apparent to the operator. However, this feature would involve some expense in increased complexity of construction.

This type of differentiator consists of a frame which is placed upon the paper, rolling under the control of the operator, in the x-direction, on the rollers R. As it progresses across the paper, the operator constantly adjusts the direction of the index wire c to maintain it parallel to the curve. This angular motion is transmitted to wheel w by an elbow mechanism similar to that used on drafting machines. As wheel w is rigidly attached to bar d, the latter will duplicate the angular position of wire c.

Bar d is rigidly fastened to wheel w and rotates with it. The distance a from the wheel to the frame carrying the pointer e is fixed; thus motion of d will cause the intersection of d and the support, namely point e, to fall above the wheel w at a distance dy/dx, which will be equal to a multiplied by the tangent of the angle to which c has been turned. A pencil placed at e will then continuously trace a curve which is the derivative of the curve which c follows.

There are several links in this mechanism, and any lost motion in the train will cause inaccuracies in the differentiation. It is easy, however, to retrace the record and eliminate errors due to this and other sources. In effect, the curve can be smoothed by repetition. After the differentiation is completed, it is not necessary to further refine the curve. Further differentiations may be made directly from this record without any copying or redrawing. It will be noted that the tracing wire c follows behind the marking point e by a short distance. This offset is required by the physical construction of the machine. Its only effect on the work is to prevent the values of both the curve and its derivative at the same point from being read on a common vertical.

NUMERICAL DIFFERENTIATION: The previous methods have required either careful draftsmanship or an expensive instrument. The numerical differentiation method requires neither, and also provides a method in which the determination of higher derivatives is independent of the first ones. In fact, it is not necessary to determine any derivative other than the one actually desired. For example, calculation of a third derivative may be done directly, without previous calculation of the first and second derivatives—an advantage not enjoyed by any other method.

While the method can be employed directly from the formulas, it may be desirable to study its foundations in order to make full use of its potentialities.[3] An extension of Newton's Method of Interpolation, it requires for its application values of the function separated by equal values of the independent variable. From any recorded curve, such as *Fig. 6*, a series of

X (sec)	*Y* (in.)	*a*	*b*	*c*	*d*
0.00	4.34				
		.03			
0.01	4.37		.01		
		.04		.00	
0.02	4.41		.01		.00
		.05		.00	
0.03	4.46		.01		−.06
		.06		−.06	
0.04	4.52		−.05		.11
		.01		.05	
0.05	4.53		.00		−.05
		.01		.00	
0.06	4.54		.00		−.01
		.01		−.01	
0.07	4.55		−.01		.02
		.00		.01	
0.08	4.55		.00		.04
		.00		.05	
0.09	4.55		.05		−.05
		.05		.00	
0.10	4.60		.05		.07
		.10		.07	
0.11	4.70		.12		−.08
		.22		−.01	
0.12	4.92		.11		−.18
		.33		−.19	
0.13	5.25		−.08		(−.35)
		.25		(−.54)	
0.14	5.50		(−.62)		(1.49)
		(−.37)		(.95)	
0.15	5.13		(.33)		(−1.27)
		−.04		(−.32)	
0.16	5.09		.01		(.32)
		−.03		.00	
0.17	5.06		.01		.00
		−.02		.00	
0.18	5.04		.01		−.01
		−.01		−.01	
0.19	5.03		.00		
		−.01			
0.20	5.02				

rectangular coordinate values may be determined as follows:

Abscissa	x_1	x_2	x_3	.	. .	x_{n-1}	x_n
Ordinate	y_1	y_2	y_3	.	. .	y_{n-1}	y_n

where, as previously noted, $x_3 - x_2 = x_2 - x_1 = x_n - x_{n-1} = h$ for all points measured. From these measured values of y, successive differences a, b, c, d, and so on, can be computed. For example,

$$\begin{array}{lll} y_2 - y_1 = a_1\,; & y_3 - y_2 = a_2\,; & \text{etc.} \\ a_2 - a_1 = b_1\,; & a_3 - a_2 = b_2\,; & \text{etc.} \\ b_2 - b_1 = c_1\,; & b_3 - b_2 = c_2\,; & \text{etc.} \end{array}$$

and so on, as far as desired.

A complete table may then be prepared as in TABLE I. Arrangement of the figures in this zig-zag manner facilitates maintaining their positions and relative order. A corresponding numerical series derived from *Fig.* 7 is shown in TABLE II.

To find the derivatives at any point, apply the following formulas:

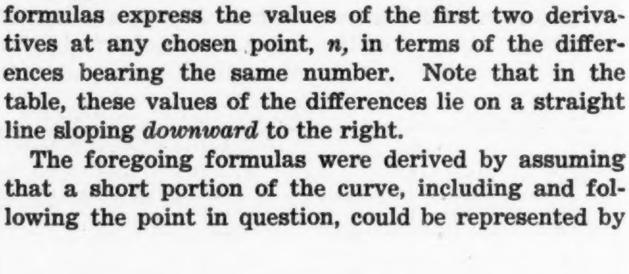
$$\left(\frac{dy}{dx}\right)_n = \frac{1}{h}\left(a_n - \frac{b_n}{2} + \frac{c_n}{3} - \frac{d_n}{4} + \ldots\right) \quad (1)$$

$$\left(\frac{d^2y}{dx^2}\right)_n = \frac{1}{h^2}\left(b_n - c_n + \frac{11}{12}d_n + \ldots\right) \quad \ldots\ldots (2)$$

Stripped of their mathematical symbolism, these formulas express the values of the first two derivatives at any chosen point, n, in terms of the differences bearing the same number. Note that in the table, these values of the differences lie on a straight line sloping *downward* to the right.

The foregoing formulas were derived by assuming that a short portion of the curve, including and following the point in question, could be represented by

Fig. 6—Definitions for numerical differentiation. Distance h must be constant for any series of readings



an algebraic power series. Then the value of the curve at point n is

$$Y_n = Y_o + px_n + qx_n^2 + rx_n^3 + sx_n^4 + \ldots.$$

and at Y_{n+1} it is

$$Y_{n+1} = Y_o + p(x_n + h) + q(x_n + h)^2 + r(x_n + h)^3 + s(x_n + h)^4 + \ldots.$$

Similar expressions are set up for Y_{n+2}, Y_{n+3}, and Y_{n+4}. The first derivative of the curve at $x = n$ is, of course,

$$\left(\frac{dy}{dx}\right)_n = p + 2qx_n + 3rx_n^2 + 4sx_n^3 + \ldots.$$

and the second derivative is

$$\left(\frac{d^2y}{dx^2}\right)_n = 2q + 6rx_n + 12sx_n^2 + \ldots.$$

The constants p, q, r, and s are determined in terms of the differences a, b, c, and d, thus giving the expressions desired.

Compute, for example, the first and second derivatives at the point 0.06-second. At that point, y = 4.54 inches, $a = .01$, $b = -.01$, $c = .01$, $d = .04$ and, substituting in Equation 1,

$$\frac{dy}{dx} = \frac{.01 + .01/2 + .01/3 - .04/4}{.01}$$

$$= .83 \text{ in./sec}$$

and

$$\frac{d^2y}{dx^2} = \frac{-.01 - .01 + (11 \times .04)/12}{.0001}$$

$$= 170 \text{ in./sec}^2$$

In order to compute these two derivatives, it was not necessary to prepare the entire table; only the values at 0.06-sec and the four succeeding points were required. This permits a small part of a curve to be checked without checking the entire record. It is to be noted that it is not possible to obtain the needed differences at the end of the table. If it is necessary to do work in this part of the curve, the end can be more closely approached by taking the values of the curve at closer intervals of x.

Effect of Discontinuity

When the derivative is calculated at x = 0.14-sec, it is found that the plotted value as laid in on *Fig.* 7 is not in agreement with the curve. This occurs because there is a discontinuity between 0.14 and 0.15, thus violating the necessary condition that the curve be smooth in the interval over which the differences

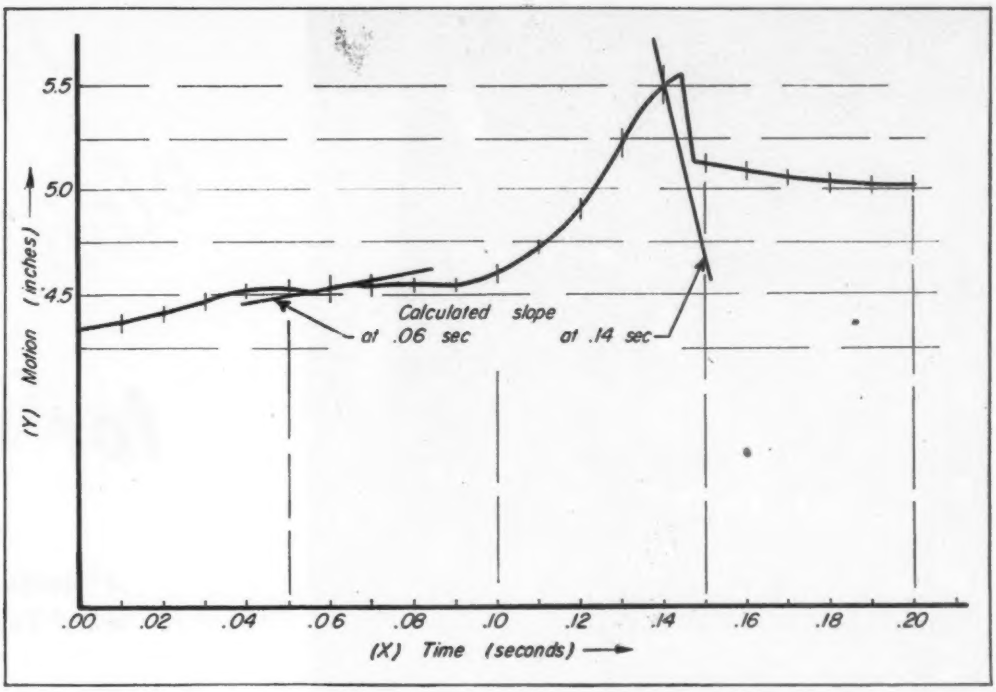


Fig. 7—Time-motion curve, showing velocities at two points determined by method of successive differences. Apparent error at .14-sec point is due to discontinuity immediately following it

are taken. The slope of the portion of the curve lying between 0.14 and 0.15-sec must be separately computed, and any values of the differences whose computation has required crossing the discontinuities must be rejected. These values have been placed in parentheses in the table. If this is not done, the computations will produce values for a curve which passes smoothly through all the points used.

In the method described here, the various derivatives have been based on those parts of the curve which immediately follow the point in question. It may be argued with some logic that the trend of a curve is more dependent upon that portion which precedes the selected point. To evaluate a curve in terms of preceding points, the successive differences are tabulated exactly as in TABLES I and II, but the differences lie on a line sloping *upward* to the right. Instead of Equations 1 and 2, the following formulas will apply:

$$\left(\frac{dy}{dx}\right)_n = \frac{1}{h}\left(a_{n-1} + \frac{b_{n-2}}{2} + \frac{c_{n-3}}{3} + \frac{d_{n-4}}{4} + \ldots\right) \quad (3)$$

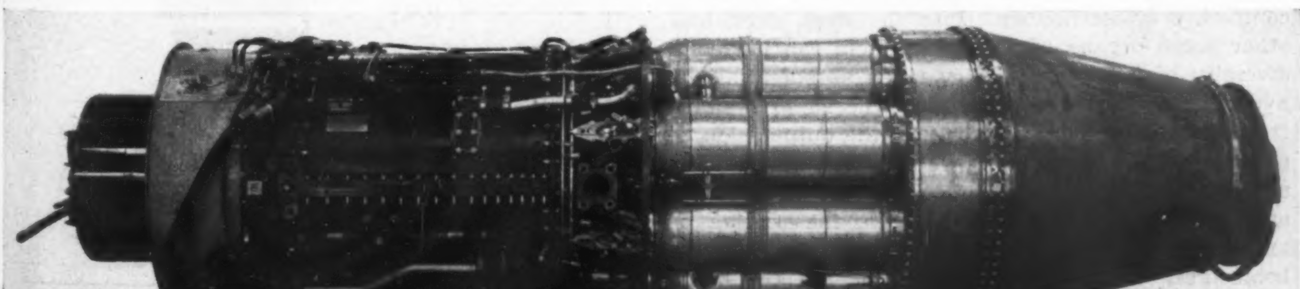
$$\left(\frac{d^2y}{dx^2}\right)_n = \frac{1}{h^2}\left(b_{n-2} + c_{n-3} + \frac{11}{12}d_{n-4} + \ldots\right) \quad (4)$$

It will be observed that this procedure does not give values of derivatives near the beginning of a curve, just as the use of Equations 1 and 2 and following points fails to give values near the end. By using both procedures the entire curve may be evaluated, including regions near a discontinuity. Also, if it is desired to evaluate the curve in terms of the trend both preceding and following a selected point, this may be accomplished by using both procedures.

REFERENCES

1. Hawkins, G. A., and Balleisen, C. E.—"High Speed Photography," MACHINE DESIGN, Aug., 1947, Page 127, and Sept., 1947, Page 121.
2. Cousins, F. W.—"Simplified Analysis," MACHINE DESIGN, Dec., 1947, Page 121.
3. Lipka, J.—*Graphical and Mechanical Computation*, John Wiley & Sons Inc., New York, 1918.

Shown below is the General Electric TG-180, most powerful jet engine now in production in this country. With a rating of approximately 5000 pounds thrust, which is equivalent to about 10,000 hp at the top speed of the new planes being built to utilize it, the new engine has undergone extensive ground and flight tests. It has been installed as the powerplant of the North American F-86A and has been altitude tested in G.E.'s B-29 flying laboratory



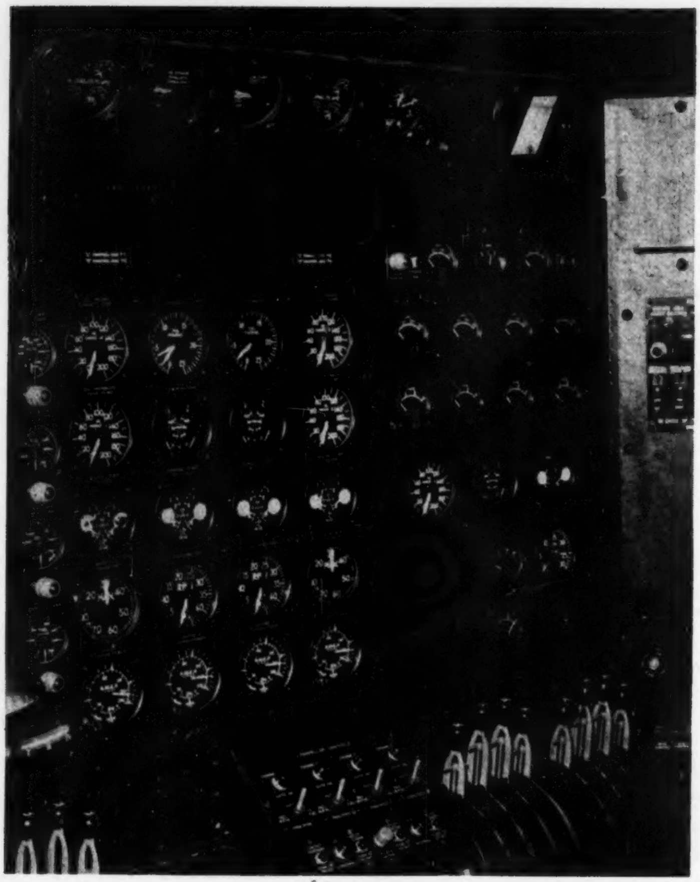


Fig. 1—Huge, complicated engineers' control instrument panel on the new Martin transport "Hawaii Mars"

Designin

for Quick, A

A review of psychological fin ward design of instruments fo

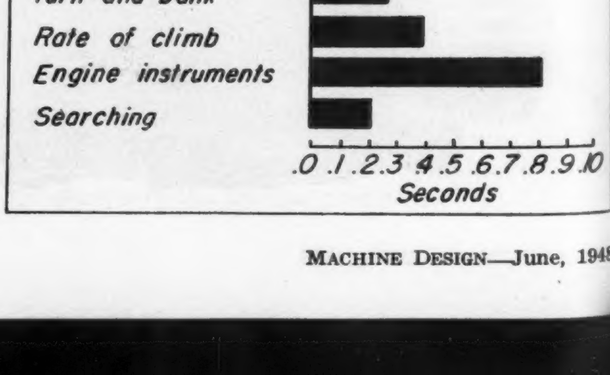
By Walter F. Grether
Aero Medical Laboratory
Wright Field, Ohio

THERE are probably few of our activities to which the well known adage, "It is human to err" is more applicable than to the reading of instruments. And there is probably no other field of human activity in which instrument-reading errors can be as expensive as they are in aviation. Many aircraft and their human cargoes have been lost because of errors that anyone might make in reading airspeed, altitude, heading, manifold pressure, or any of the other indications essential for successful flight and navigation, *Fig.* 1. Although this paper is concerned primarily with human errors in the reading of aviation instruments, the research results are applicable to all types of instruments.

In the consideration of instrument reading it is helpful to think of the human being as an extremely complex servomechanism. Into the eyes, ears, and other sense organs of this mechanism can be fed a diversity of information, very much as potentials or hydraulic pressures are fed into true servo systems from suitable sensing devices. On the output side of our human servomechanism we can have a variety of actions such as the operation of control levers, knobs, and switches, the aiming of a gun, the writing of an entry into a navigation log, an adjustment on a bombsight, or a spoken instruction. On the other hand, our human servo may not produce any external action, but may instead store the incoming data for the control of future action.

Considered as a servo link in the operation of complex equipment, the human being has several advantages as well as disadvantages by comparison with conventional electromechanical systems. The human capacity for learning, for the handling of diverse and complex data, and for the exercising of critical judgment could be matched, if at all, only by prohibitively complex servo systems or automatic computers. On

Fig. 2—Average instrument fixation time of 20 pilots during regulation ILS landing approaches



Based on a paper presented at the recent SAE National Aeronautic and Air Transport meeting in New York.

nstrument Dials

ate Reading

keynotes the first steps to- ease and accuracy in reading

the other hand, the human being cannot match a properly functioning servo system in rapidity of action and freedom from unpredictable errors. We can, however, increase considerably the speed and probability of correct action of our human servo by improvements in the instruments which supply information to it. It is toward this end that the research reviewed in this article has been devoted.

In order to understand the problem better it is important to know what kinds of errors normally occur in instrument reading. From a post-war investigation it became evident, for example, that multi-revolution aircraft instruments, such as the altimeter, are frequently misread by a complete revolution of the sensitive pointer. Also, some heading and attitude instruments are susceptible to a reverse interpretation leading to control of the aircraft in the opposite of the desired direction. Especially noteworthy is the fact that most gross errors in instrument reading were found to have resulted from faulty interpretation rather than from difficulties in legibility or acuity. The major and most serious difficulties, in other words, are not in seeing or hearing the presented information, but in making the correct mental interpretation.

How Instruments Are Read: In designing any given instrument, the manner in which it is to be used, or the purpose for which it is to be read must be known. There are at least three types of instrument reading: (1) Check reading for assurance of a null, normal or desired indication, (2) qualitative reading for the meaning of a deviation from a null, normal or desired indication, and (3) quantitative reading for the actual numerical value of an indication. Among the existing aircraft instruments there are some that serve only one or two of these three reading functions. A warning light, for example, serves only for check reading. Engine instruments are, by and large, merely check-read, although qualitative and quantitative readings are also possible and sometimes necessary. Still other instruments, such as the cross pointer and horizon bar of the gyro horizon serve only the check and qualitative reading

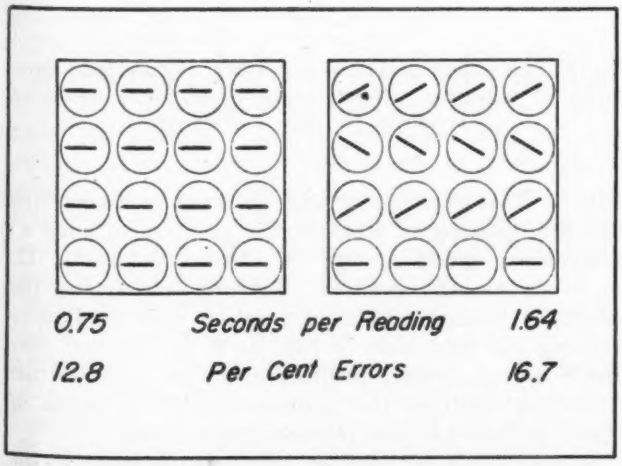


Fig. 3—Speed and accuracy of check reading of 16 engine instruments with horizontal versus mixed pointer alignment

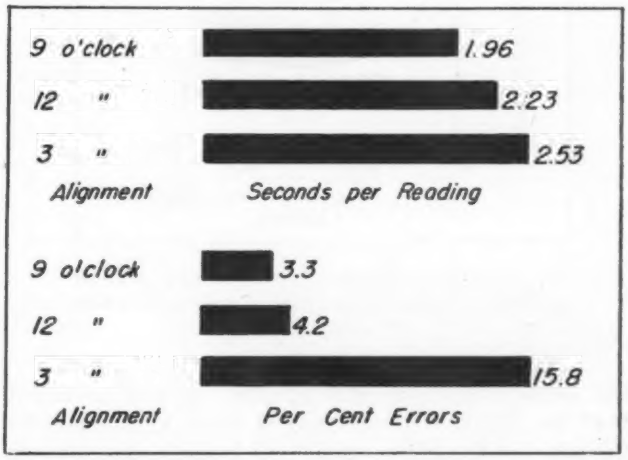
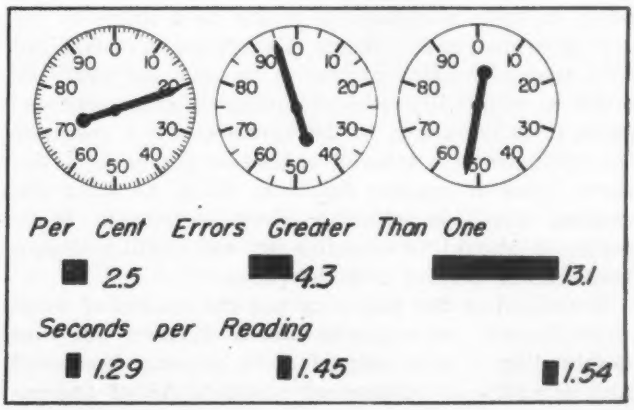


Fig. 4—Above—Speed and accuracy of qualitative reading of 16 engine instruments with pointers aligned in the 9, 12, and 3 o'clock dial positions

Fig. 5—Below—Effect of omitting graduation marks upon speed and accuracy of dial reading. Six men read each dial 120 times



functions. Most other flight instruments can and probably should satisfy all three reading purposes.

Just as the reading purpose or function will differ for different instruments, so, also, will it differ with the task being performed by the reader. It is possible, in a normal operating situation to get some evidence of the types of reading being performed from a study of the reader in action. In reading instruments, as in any other kind of seeing, it is necessary for the eyes to be fixed momentarily on each instrument. From motion picture records of the pilot's face it is possible to determine the length of the eye fixations on each instrument and the frequency with which each instrument was checked. Some preliminary results of one such study now under way are shown in *Fig.* 2, which gives the average time per eye fixation on each instrument during a landing approach using

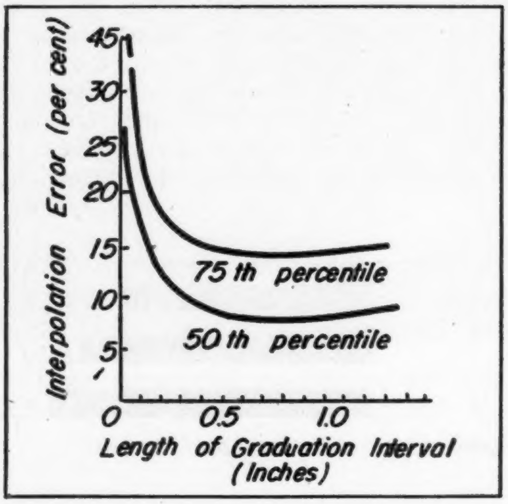


Fig. 6—The accuracy of interpolating pointer position between graduation marks as function of scale interval

the cross pointer or ILS system. It will be noted that the fixation times ranged from approximately 0.3 sec. for the most rapidly read single instruments to over 0.7 sec. for the cross pointer. Quantitative readings, however, normally require considerably longer periods. Although strictly quantitative readings may be made infrequently during flight, many of the most hazardous errors made are of this type.

This threefold classification in terms of check, qualitative, and quantitative instrument reading appears to have considerable utility as a guide to research on instrument design. Design requirements for each type of reading appear to be quite different. In order to eventually achieve optimum instrument designs it is necessary to determine through research the optimum principles of indication for each of the three types of reading function. Then, knowing the reading purposes which a given instrument is to serve, it should be possible to successfully design instruments to serve those purposes.

Presented in the following are the results of some psychological experiments which further our understanding of how design factors influence the speed and accuracy of instrument reading. All of the experiments are recent, and are only the beginning in a new scientific approach, but they demonstrate what can be accomplished by this line of investigation.

CHECK READING: Speed of check reading is of particular importance in the case of engine instruments, many of which are of concern only when their readings fall outside the normal operating range. It is highly desirable that a pilot be able to glance at his array of engine instruments and be able to detect quickly any indications of malfunction. In an effort to obtain superior engine instrument arrangements the Equipment Laboratory of the Air Force Air Materiel Command is working toward rectangular arrangements of instruments with uniform pointer alignment. Psychological studies have been conducted with such rectangular arrays of simulated instruments and *Fig.* 3 shows some of the results for check reading of 16 instruments simultaneously. The results show that when horizontal pointer alignment is used it is possible to check and respond to a group of 16 instruments in 0.75 seconds, which is approximately the time required for single instruments. The results also show that a mixed alignment condition considerably increases the difficulty of checking such a group of engine instruments.

QUALITATIVE READING: A study of qualitative reading was also carried out using the group of 16 simulated engine instruments illustrated schematically in

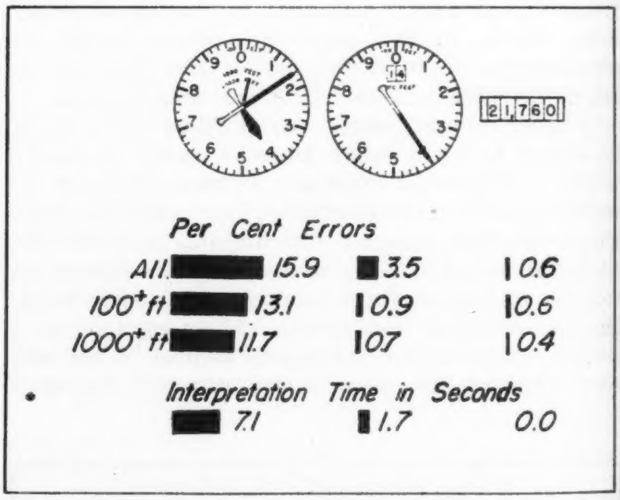


Fig. 7—Speed and accuracy of reading altitude from three types of indicator. Ninety-seven USAF pilots made 12 readings on each instrument

Fig. 3. This experiment was designed to answer the specific question of whether the pointers of such an instrument group should be aligned at the 9, 12, or 3 o'clock dial position. Findings concerning the effects of pointer alignment position upon qualitative reading are presented in *Fig.* 4. It is apparent that the 9 o'clock pointer position gives the best and the 3 o'clock position the poorest results in terms of speed of response and freedom from errors.

A reasonable explanation for the superiority of the 9 o'clock position can be found in the direction of

(*Continued on Page* 208)

Nonmetallic Diaphragms

. . . their design and application

By J. H. Swartz
Engineer
Linear, Inc.
Philadelphia

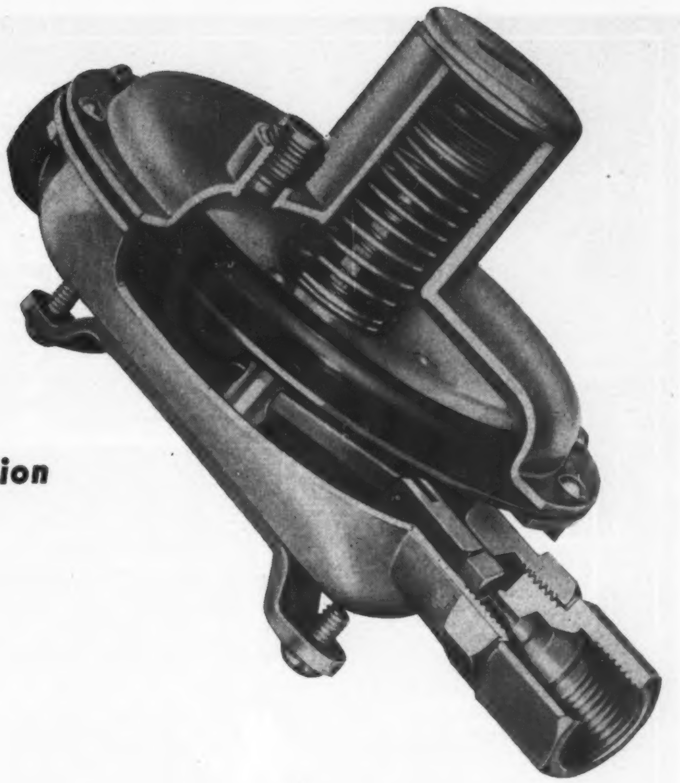
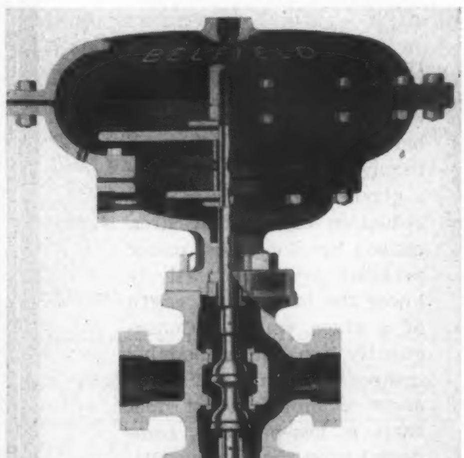


Fig. 1 — Above — Differential type diaphragm is used in this propane-butane pressure regulator. Details of this regulator are shown in Fig. 3

Fig. 2—Below—Fuel-pressure control valve utilizes two differential-pressure diaphragms



NEW fields of diaphragm application and service have been opened in recent years by improved materials and designs. Formerly, the limitations imposed by available materials severely restricted diaphragm usage. During the last decade, however, synthetic materials have been developed which will withstand an ever-expanding range of operating conditions. Having this greater variety of materials to use, design engineers are giving more thought to diaphragm design possibilities and to the stresses which must be distributed properly in order to provide satisfactory operation. In the past, each diaphragm installation has been a tailor-made design and much of the research has been that of individuals or corporations. As a result, there has not been, to the writer's knowledge, any compilation of design data generally available to the engineering profession. This article is, therefore, a preliminary attempt to bring some of the loose ends together in the hope that it will be the starting point for more detailed analysis in the future.

For the purposes of this discussion, the application of flexible diaphragms has been arbitrarily divided into two classifications corresponding to the major functions they are intended to perform in service. The first and probably the most widely used group is that which is intended to multiply a force to produce thrust for various actuating purposes, *Fig.* 1. The second and probably newer group is that which is used chiefly to separate liquids, gases or combinations of the two. Obviously, the function of the former should be accomplished with minimum mechanical losses consistent with adequate strength of the diaphragm material for the service conditions to be met.

Three major factors affect the performance of a flexible, nonmetallic diaphragm. They are: First, the physical properties of the material; second, the chemical properties of the material; and third, the mechanical design of the diaphragm itself. These factors will be discussed briefly in the sequence given.

Physical Properties of Materials: The general physical-property requirements for the force multiplication or unbalanced-pressure type of diaphragm are somewhat different than for the fluid-separation type due to the different functions performed by each. These major requirements are in order of their importance to the design engineer:

1. *Burst Strength*: This property is controlled chiefly by two other properties commonly used in the

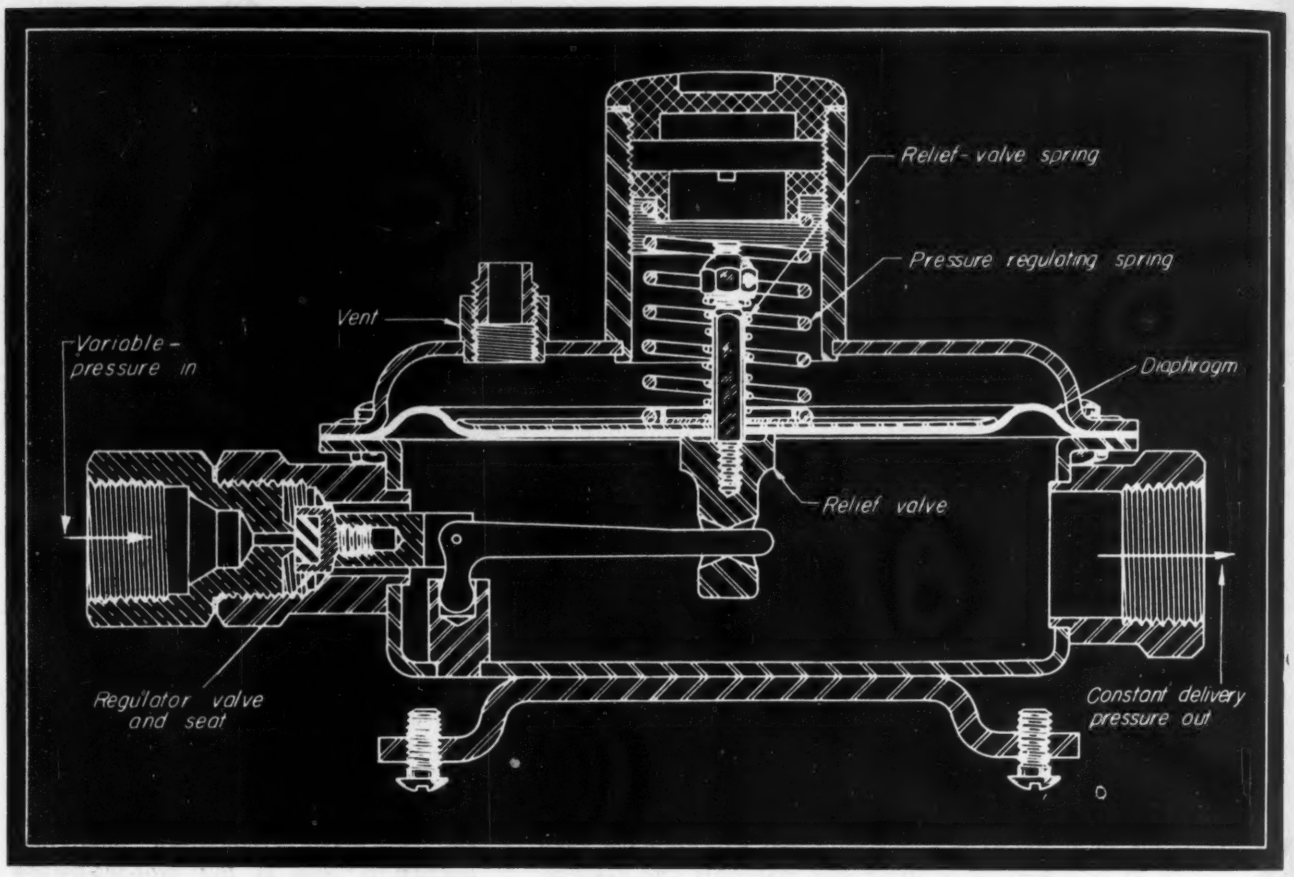


Fig. 3—Above—Cross-section of regulator valve shown in Fig. 1. Diaphragm has central relief hole to accommodate excess pressures

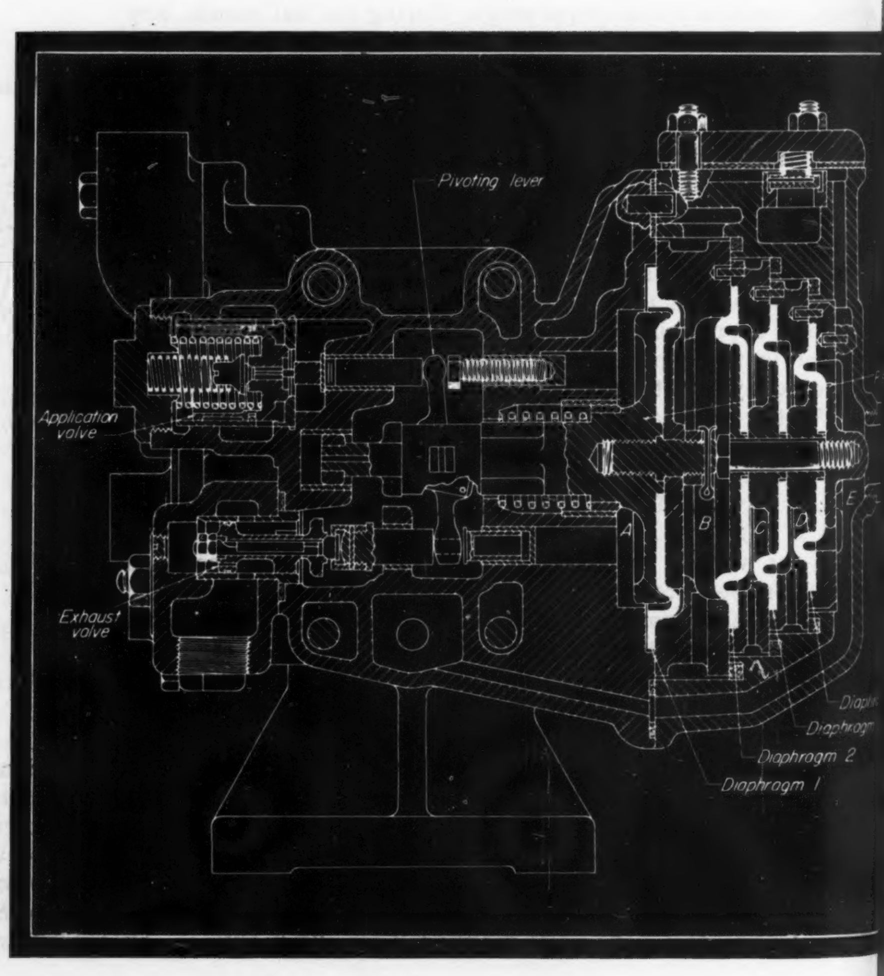


Fig. 4—Cross section of railway air-brake relay valve. Use of diaphragms of graduated areas make possible preselected pressure reductions from a constant-pressure source

rubber industry, i.e., tensile strength and modulus. Since ultimate tensile strength is based on the tensile stress required to cause failure for a given area of section, any reduction of sectional area caused by elongation under pressure will progressively lower the bursting strength of a given sample. Consequently, a high-modulus compound should ordinarily show a higher burst test than a low-modulus compound even though the ultimate tensile strengths of both are approximately the same

2. ***Flexibility***: This is a term usually employed to describe the relative deforma-

tion or deflection of a given material when subjected to a given load. This property is dependent on modulus, low-modulus compounds usually being described as "flexible" compounds and high modulus compounds being called "stiff" compounds

3. *Fatigue Resistance*: This property may be comparatively evaluated by reference to the resilience of the compound. Generally speaking, the most resilient compounds are those which most nearly recover their original shape after release of the deforming force. This simply means that a minimum portion of the energy causing deformation is converted into heat (hysteresis loss). Thus, the more resilient a compound is, the less heat is built during repeated stress cycling and, consequently, reductions in tensile strength, tear resistance and other physical properties caused by heat are minimized.

In the general category of fluid separation, or balanced pressure diaphragms, burst strength is of relatively minor importance, being replaced by flexibility and fatigue resistance. The order of importance of the two properties depends on the particular function the diaphragm is expected to perform.

Chemical Properties of Materials: The chemical properties of a compound insofar as they are related to diaphragm service can be narrowed to two factors. They are: First, the permeability of the material to gases which may be in contact with the diaphragm surface; and second, the resistance of the material to reduction of physical property values through exposure to high temperatures, or destructive fluids.

Comparison between various basic polymers in their uncompounded and compounded states with respect to their permeability to four common gases is given in Table I. Variations, however, in the molecular structure of the polymer, in compound ingredients and in production processes will all affect the gas permeability of the finished product. Generally, gas permeability is of significance only in diaphragm applications of the balanced-pressure or separation type.

Resistance of the diaphragm material to swelling and deterioration in the presence of destructive liquids or gases is obviously important, since changes in these properties will alter the orginal physical properties incorporated into the material. Furthermore, change in original physical properties produces, in most cases, change in diaphragm performance. Selection, therefore, of the proper material to meet specific service conditions should be left to the diaphragm manufacturer unless, of course, test data showing proved suitability of a particular material is available to the designer.

Design Considerations: Requirements governing the design of the diaphragm and the assemblies within which it operates must also be given careful consideration. The first of these is space limitation. In the case of existing equipment into which a diaphragm has been introduced the reason for space limitation is apparent. Other space-limiting conditions are generally dictated by the special service into which the whole assembly is to be put.

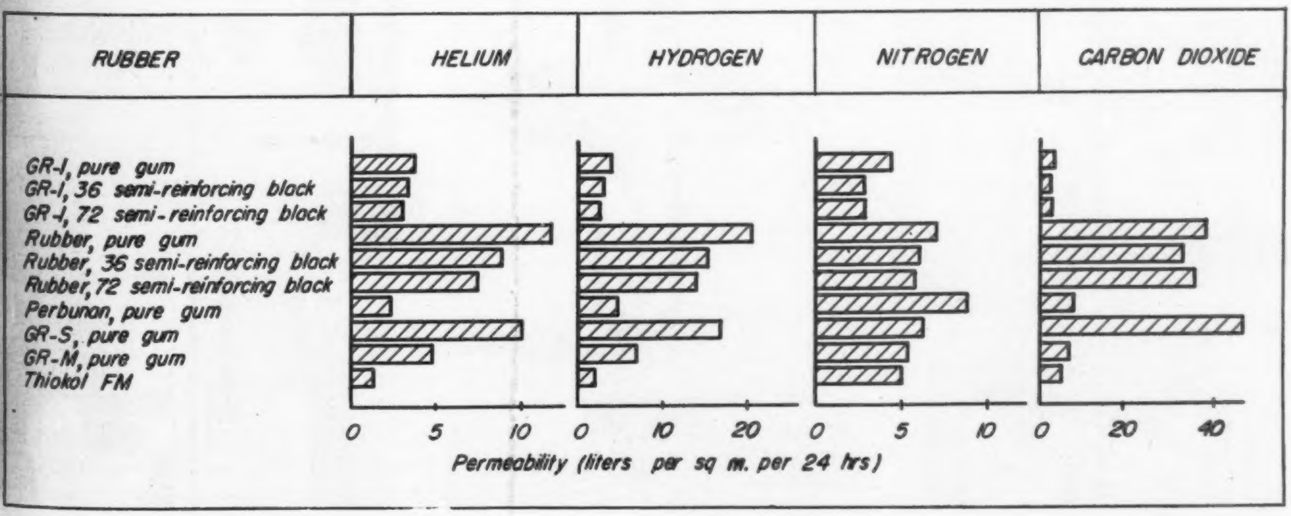
Deflection Amplitude Limits Design

Required amplitude of deflection (stroke) of the diaphragm also materially limits the design of the diaphragm due to the desirability, in the case of elastic diaphragms, and the necessity, in the case of reinforced diaphragms, of incorporating sufficient material into the surface area to permit full required deflection without stretch. This is usually accomplished by designing single or multiple convolutions into the diaphragms. Necessary diaphragm sensitivity (ability to deflect with minimum applied force) governs the thickness of the material. To a lesser extent it determines the construction, that is, whether it is to be homogeneous or reinforced.

An aspect of diaphragm design too frequently neglected is that of compression sealing. With the wide variations possible in modern diaphragm design it is not entirely practical to make any sweeping recommendations or condemnations concerning this feature. Worthy of some design consideration, however, are a few general pointers which should prove useful.

The most important of these, because of its wide-

Table I—Relative Gas Permeability of Rubbers



spread misuse in industry, is control of flange compression. For each diaphragm application there is a correct "squeeze" or precompression which will provide adequate sealing without undue distortion of shape. This value should be determined, by trial and error if necessary, and should be adhered to on all production units. A satisfactory method of achieving this control is counterboring to the outside diameter of the diaphragm flange one of the two faces between which it is to be clamped, to a depth which will automatically provide the correct minimum squeeze when the clamping surfaces are brought metal to metal. This method, although not universally applicable, not only offers the advantage of uniform clamping pressure around the periphery of the flange but also insures proper adjustment during the replacement in the field.

Flange-width to thickness ratio usually varies from 4:1 to 10:1. Since most diaphragm materials are essentially incompressible, that which appears to be a small increase in flange squeeze may cause an expansion in flange width of 4 to 10 times this value and result in detrimental buckling of the diaphragm surface.

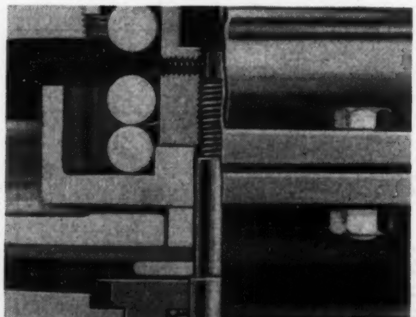
This condition can be somewhat alleviated by providing sealing ribs or beads on the clamping surface of the diaphragm. This will also minimize the bolt prestressing necessary to seal the flange, since unit clamping pressure will be increased by reducing the effective clamping area. Serrated metal flanges, however, should be used with caution since they frequently cause failure due to high stress concentrations on the material between serrations. Usually, a diaphragm design which initiates rolling action instead of buckling at the start of deflection will reduce stress concentration and will greatly assist in prolonging the diaphragm life.

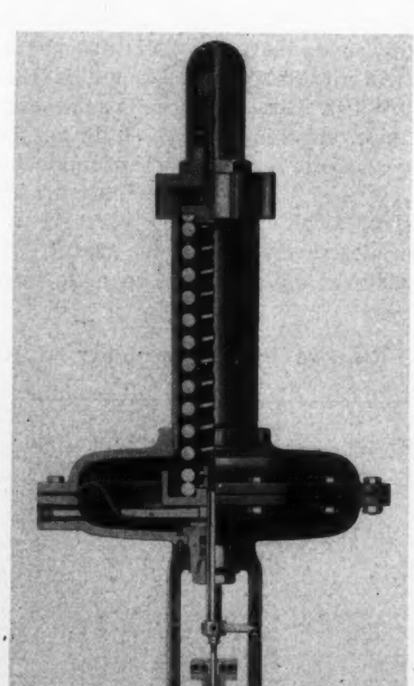
The remainder of this article will be devoted to discussing specific applications which illustrate the wide variety of service conditions and mechanical functions which can be handled by mechanical diaphragms.

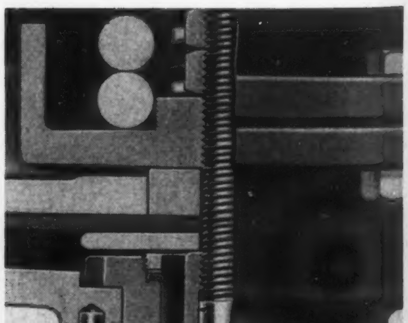
Air Operated Duplex Diaphragm Control Valve: This unit, which has a differential-pressure type diaphragm is shown in *Fig.* 2. It is designed primarily to regulate fuel pressure in industrial gas furnaces in conjunction with air-operated control instruments. Its function is accomplished by introducing an air signal, generally about 20 psi, to the upper sensitive-control diaphragm which opens the valve admitting fuel flow to the controlled line. When the fuel pressure in this line and in the lower controlled-diaphragm chamber rises to 60 psi (using the 3:1 ratio of diaphragm areas), it will balance the control diaphragm and the valve will hold its setting until the equilibrium is upset by a change either in controlled-fuel pressure or in air-signal pressure. The resulting unbalance will either open or throttle the valve to re-establish equilibrium. In this unit, a wide ratio of controlling to controlled pressures may be obtained by substituting various sizes of diaphragm assemblies.

The lower diaphragm in the valve eliminates the need for stem packings or springs, resulting in a

Fig. 5—Control-valve seal is a diaphragm of the differential type. Section of valve shows seal located just below control-diaphragm chamber. Details show old seal design at left, and new design, utilizing diaphragm as a seal, at right







pressure regulator of unusual sensitivity and control accuracy. A diaphragm design feature of considerable interest is the premoulded radius in the operating area, concave to the pressure side, which produces the initial rolling action previously discussed.

Propane Butane Pressure Regulator: Using a differential-pressure type diaphragm, this valve, *Fig*. 1 is designed for use in bottled gas (liquid petroleum gas such as butane and propane) fuel systems widely employed in rural areas. It provides the uniform outlet or delivery pressure required for optimum burner efficiency over a wide range of inlet pressures. In a unit of this type, delivery pressure is preset by initial adjustment of the spring. Any increase in delivery pressure or flow raises the diaphragm against spring compression and cuts off the inlet pressure. When delivery pressure drops below predetermined value, the spring lowers the diaphragm assembly, opening the inlet valve and permitting delivery pressure to increase until spring pressure is once again balanced.

Valve Is Incorporated Into Diaphragm

An interesting feature of this installation is the incorporation of an overload relief valve into the diaphragm itself as shown in *Fig*. 3. The relief valve, using the diaphragm as a seat, is held in a closed position by the relief-valve spring backed up by the diaphragm plate. Any increase in delivery pressure above the regulator setting caused, for example, by regulator-valve failure will raise the diaphragm off the relief valve. The clearances between the square relief-valve stem and the round hole in the center of the diaphragm will permit gas to escape from the vent until delivery pressure once more drops to the original setting, at which time the relief valve spring will again seat the relief valve.

Unusual sensitivity is provided in this valve by varying the diaphragm thickness at the flexing areas. Adequate deflection with constant effective diaphragm area is obtained by the moulded-in convolution in the diaphragm surface.

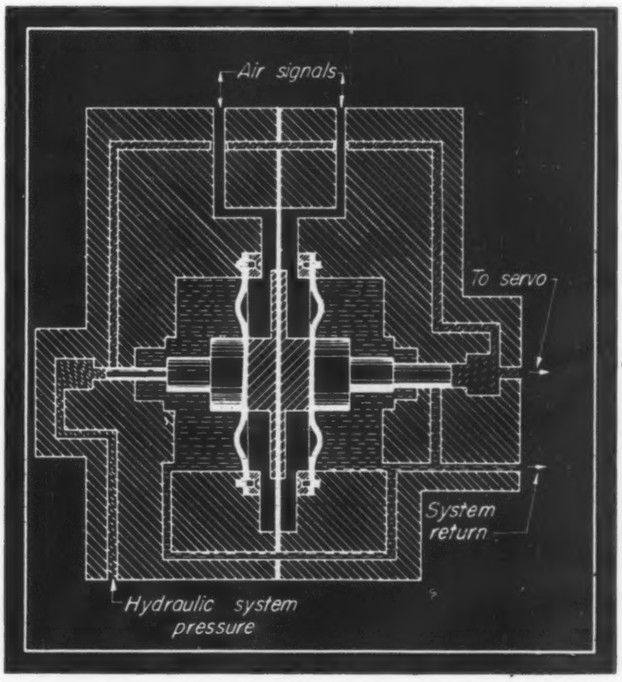
Railway Passenger-Car Airbrake Relay Valve: The function of this valve is to limit the brake-cylinder pressure in relation to train speed as controlled by an electric speed governor through solenoid valves. As shown in *Fig*. 4, the diaphragms are of the differential-pressure types. When brakes are applied at train speeds exceeding approximately 65 mph, a high-speed solenoid valve is opened by the speed governor. admitting air-line pressure to diaphragm chamber *B*. Under this pressure, diaphragm 1 is moved to the left and, acting through the pivoting lever, closes the exhaust valve and opens the application valve. This admits air-line pressure into the diaphragm chamber and thence to the brake-cylinder line. When line pressure is reached in valve chamber *A*, diaphragm 1 becomes balanced, maintaining line pressure on brake cylinders.

As the train speed falls below 65 mph, a medium-speed solenoid valve admits brake-line pressure to chamber *C*, and pressure in *B* is released. Since, however, the area of diaphragm 2 is only 80 per cent of the area of diaphragm 1, the piston will move to close the application valve and open the exhaust valve until valve-chamber pressure (or brake cylinder pressure) is 80 per cent of brake pipe pressure. Further slowing of train will reduce brake-cylinder pressure to 60 per cent, then 40 per cent of air pipe pressure through action of diaphragms 3 and 4 which have areas 60 per cent and 40 per cent, respectively, of diaphragm 1. This diaphragm installation illustrates an effective method of obtaining various preselected pressure reductions on actuating equipment from a constant-pressure source without special auxiliary equipment.

Valve Stem Seal for Diaphragm Control Valve: The purpose of this assembly, which utilizes a differential-pressure type diaphragm, is to replace a conventional V-ring packing installation as shown in *Fig*. 5. Absolute air tightness and low mechanical resistance to axial motion and minimum maintenance are the major requirements. In order to accomplish this function a somewhat unique combination of features was incorporated into this design.

First: A thin elastic synthetic rubber was selected for the diaphragm material in order to meet the requirement of maximum flexibility. Second: A rolling type of diaphragm was chosen. This was done to achieve small diameter, since this seal diaphragm has the effect, under pressure, of cancelling a portion of the effective area of the main controlling diaphragm. Also, since the diaphragm assembly was required to be interchangeable with the old stuffing-box assembly, it was necessary to limit the diaphragm diameter while retaining a relatively long stroke. Third: The chamber into which the diaphragm fits was fully enclosed and conformed to the diaphragm shape to limit inflation under pressure. Fourth: To facilitate as-

Fig. 6—Transfer valve employs balanced-pressure diaphragms to separate air signal from hydraulic fluid



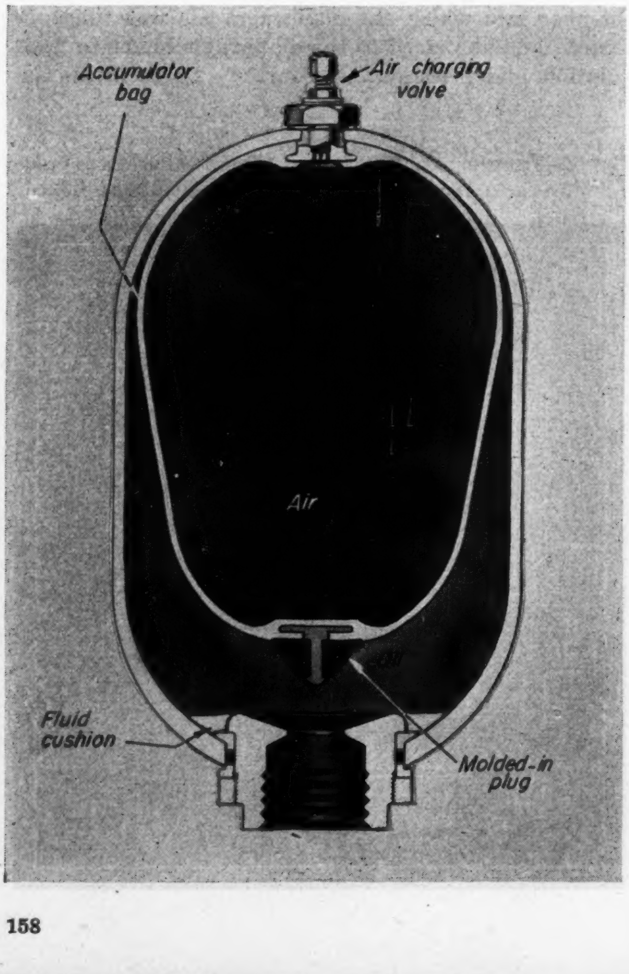
sembly, the diaphragm was molded to the shape illustrated. Secure clamping and sealing was effected by the provision of enlarged beads on both the inner and outer periphery.

The result of this design is to virtually prohibit seal friction from reducing the sensitivity of the valve to air-signal pressures transmitted by the controlling instrument.

Aircraft Automatic-Pilot Transfer Valve: The function of this valve is to transform differential air signals from the gyroscope unit into amplified hydraulic-pressure variations to actuate the related servo cylinder. Separation of the pneumatic and hydraulic fluids is accomplished by a balanced-pressure type diaphragm.

As shown in *Fig.* 6, the air signals are admitted to both sides of a central control diaphragm. When the pressure becomes greater on one side of the diaphragm, the diaphragm together with the attached piston assembly travels in the other direction. These pneumatic-pressure forces are balanced by hydraulic forces from a hydraulic-system line and a servo-cylinder line which act on the ends of the valving pistons. Thus, in neutral position, the air pressures are equal and the hydraulic pressures are in inverse proportion to the piston areas. When air pressure unbalances the assembly toward the right, the left-hand piston serves as a valve and allows full hydraulic-system pressure to flow past and act on the right-hand valve piston. As the pressures balance, the assembly moves to neutral and the left-hand valve closes. Conversely, an unbalanced air-signal pressure to the left allows servo-line pressure to bleed off to the system return until the pressure forces balance.

Fig. 7—Bag for accumulators shown in Fig. 8 are diaphragms of balanced-pressure type. Diaphragm must have walls of carefully controlled thickness; material must retain physical properties over wide temperature range



The diaphragms on each side of the control diaphragm serve to separate the return-line fluid from the air-signal chambers. For this reason they have been classified as balanced-pressure diaphragms although, in the strictest sense, there can be a pressure differential of 4-inches of mercury across either one. The major requirements of these diaphragms are: First, that they be air tight; second, that they be extremely sensitive; and third, that the thickness be held to close tolerances (diaphragm thickness is 0.012-inch). In order to insure air tightness each diaphragm is tested for leakage at 50 psi static air pressure during inspection.

Close Tolerances Held

Performance specifications for these diaphragms require that the entire valve assembly shall operate at a minimum air-signal pressure differential of 0.10-inch of Hg and that it shall be capable of completing a 100,000 cycle life test at 4-inches of Hg without diaphragm failure. The necessity for maintaining close tolerances on diaphragm thickness can be appreciated when it is realized that the total stacked tolerance of the entire diaphragm and piston assembly must not exceed 0.0075-inch to insure proper functioning of the valve.

Bag Type Hydraulic Accumulator: The purpose of the unit in this installation is to store energy in the form of hydraulic pressure to be used at intervals to actuate the automatic clamping, platen traverse and upset operations of a 800-kva flash welder. The diaphragm used is of the balanced-pressure type. By utilizing a 2 gpm hydraulic pump, charging two accumulators of sufficient capacity, enough power is stored between operating cycles to actuate this welder at a speed which would otherwise require a 100-gpm pump. The major requirements of a totally enclosed bag, *Fig.* 7, for such an accumulator are:

1. Accurate control of wall thickness to achieve uniform and predictable expansion up to 130 per cent elongation under precharged gas pressure
2. Attainment of a good joint (this type of bag must be molded in two halves) with respect to uniformly smooth surfaces, uniformity of physical properties through the joined area and impermeability to the liquids or gases used
3. Chemical resistance to hydraulic oils employed
4. Maximum retention of original physical properties over the temperature range anticipated.

The bag used in these accumulators is provided with a molded-in valve body for gas precharge. A plug or poppet is also molded into the opposite end of the bag to eliminate extrusion of the rubber when hydraulic fluid is exhausted. Provision is made at

(*Concluded on Page* 206)

MACHINE *Editorial* DESIGN

Responsibility or Opportunity?

Because of their specialized training, engineers as a class have not been prone to participate in public affairs. Although they are to be credited with the technological advances which have resulted in current high standards of living and the general well-being of the nation, they are content to leave to others the application of their developments.

That this condition is due for a change, however, is apparent from the attention now being paid to the subject. For many years the American Society of Mechanical Engineers, through its Civic Responsibilities Committee, has sponsored participation by the membership in matters relating to local, state and national government. Of late a considerable degree of success has been achieved, and engineers—singly or through committees—have demonstrated their ability to aid governmental bodies in the solution of technical and administrative problems.

Pertinent attention was focused on the role of the engineer in the future life of the nation at a recent symposium at which were presented the views of government, industry, the scientist and the engineer. All four speakers laid stress on the ever-widening vista that is opening up for the engineer and scientists in the realm of public affairs. James D. Mooney, president of Willys-Overland Motors, referred to the necessity for the engineer to prepare to assume a wider field of activity and broader social, political, economic and moral responsibilities. In discussing some of the essential factors in an engineer's education, he named: (1) the ability to express himself clearly; (2) study of history as affected by technological development; (3) basic grounding in principles of economics; and (4) recognition of moral and spiritual values in life.

Many notable examples could be cited of the accomplishments of engineers in public life. It is believed that as more members of the profession engage in activities beyond the scope of their specialized background and training, the status of the engineer will be greatly enhanced and wider recognition of his contribution to society—from all standpoints—will follow. Such activities might well be considered as the acceptance of increased opportunities rather than increased responsibilities as they have so often been termed in the past.

L. E. Jermy

DESIGNS OF THE MONTH

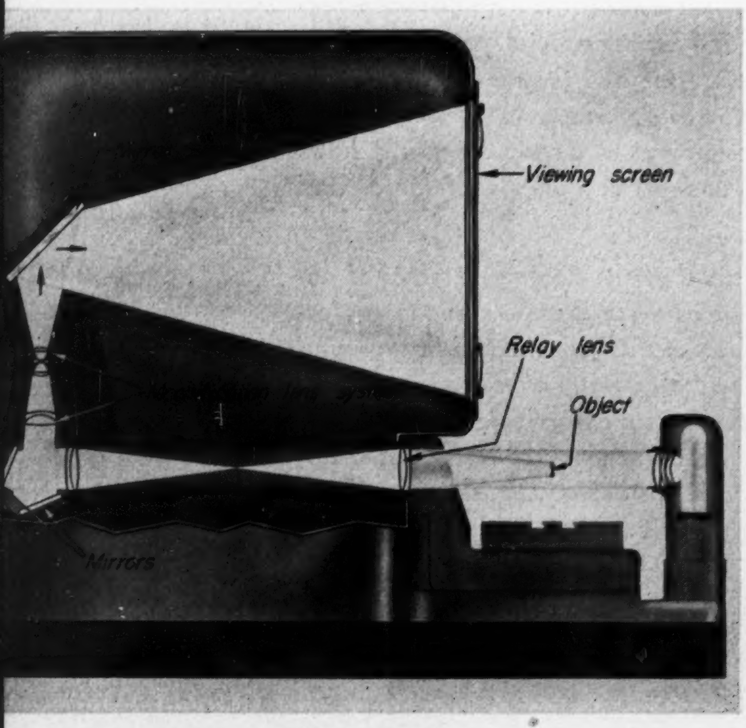
Contour Projector Uses New Optical System

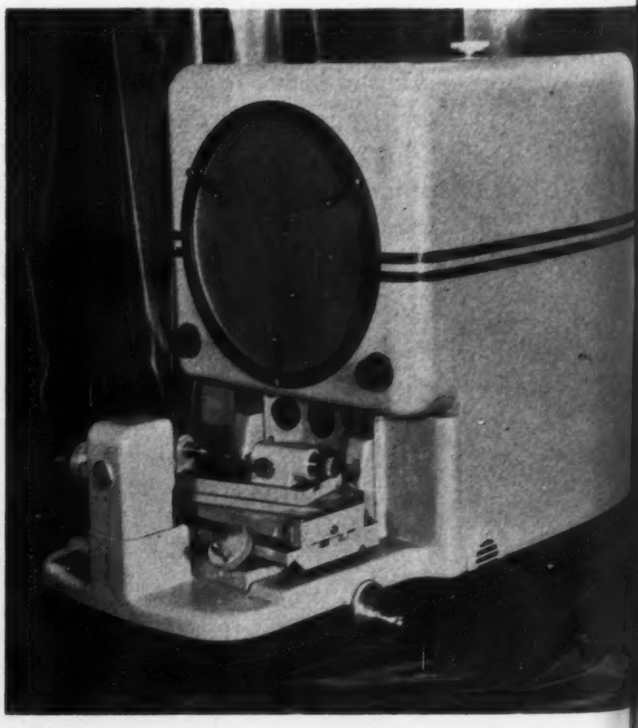
OPTICAL principles not previously incorporated in instruments of its type are employed in the contour projector, lower right. As the sectional view, below, shows, when an object is positioned on the work table, its shadow image is picked up by the relay lens. The image path is reflected upward by the two mirrors at the rear, and passes through a second lens system which provides the desired magnification. A single mirror at the top rear of the projector reflects the magnified image onto the viewing screen, which is backed up with a special lens element known as a Fresnel lens.

This Fresnel lens, similar to the lenses used for lighthouses, is a major factor in providing maximum screen brilliance. In effect, it concentrates the light passing through the viewing screen in a cylinder of the same diameter as the screen. Because of this, and because all lens elements are "Lumenized" with a microscopically thin coating of magnesium fluoride to increase light transmission, the projector can be used in fully lighted rooms without hood or curtains.

Use of the relay lenses fulfills a double purpose; permitting the magnifying lens to be mounted in the rear of the dust-tight cabinet and providing a constant working distance of eight inches between the part under inspection and the first lens of the projection system. In addition, the relay lenses serve with the twin mirrors located at the bottom rear, to provide an erect image on the screen.

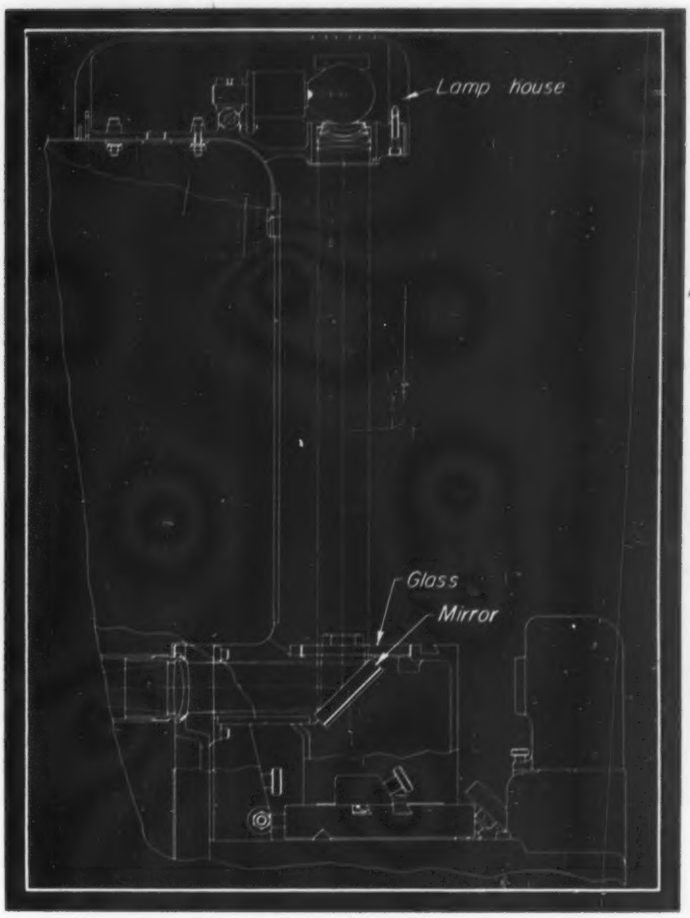
All magnifying lenses are parfocused, and once the projected image is in focus on the screen, magnification may be changed without refocusing. To effect such changes easily where they are frequent, a lens turret is supplied as an accessory. This affords a choice of five magnifications simply by turning a knob at the top of the instrument to position the de-





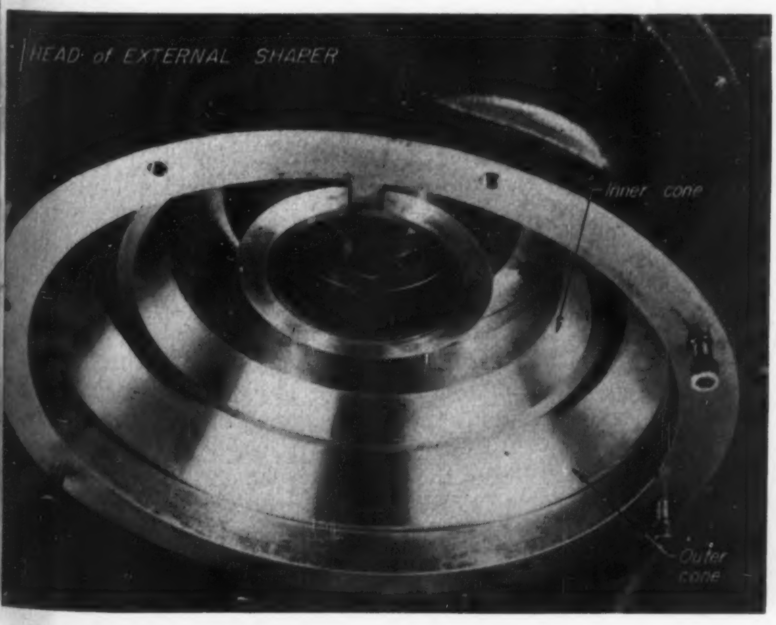
sired lens at a click stop.

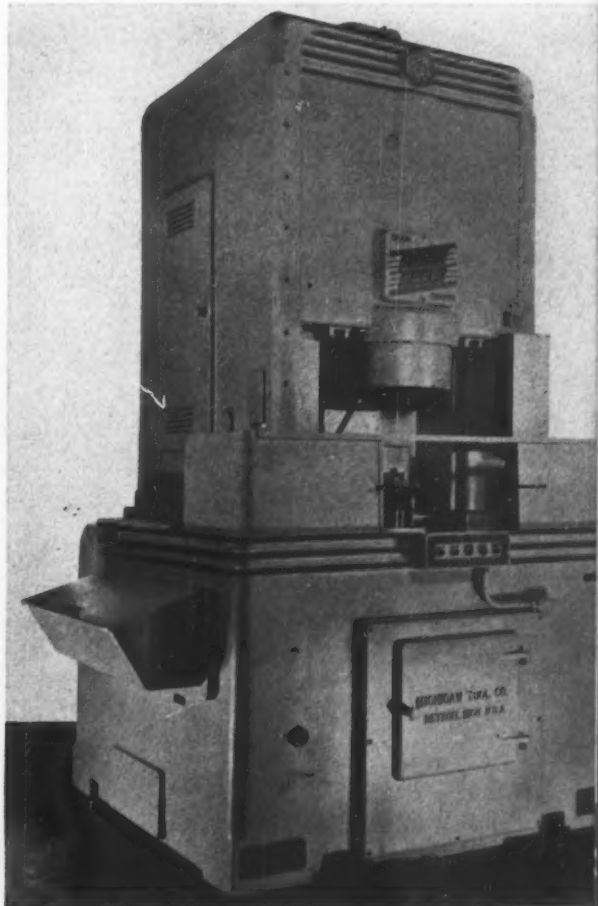
Another accessory, shown at the right, provides a system of vertical projection for inspecting thin or flat parts. A lamp house is attached to the top of the machine and its beam is directed to a glass work table mounted on the standard table. A mirror, set at 45 degrees, picks up the shadow image of the part resting on the glass and directs the light beam into the relay lens. Manufacturer: Eastman Kodak Co., Rochester 4, N. Y.

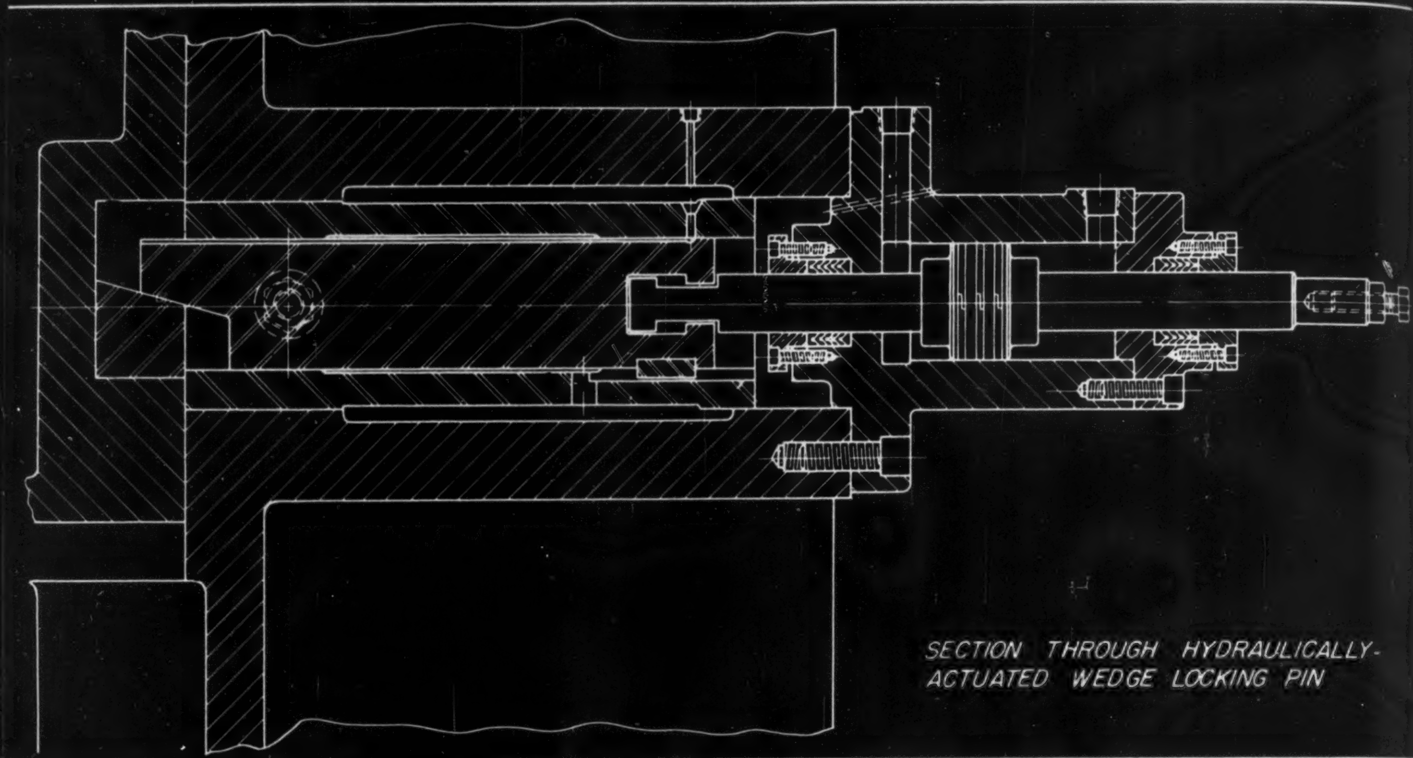


Shaper Head Locked by Hydraulically-Actuated Wedge

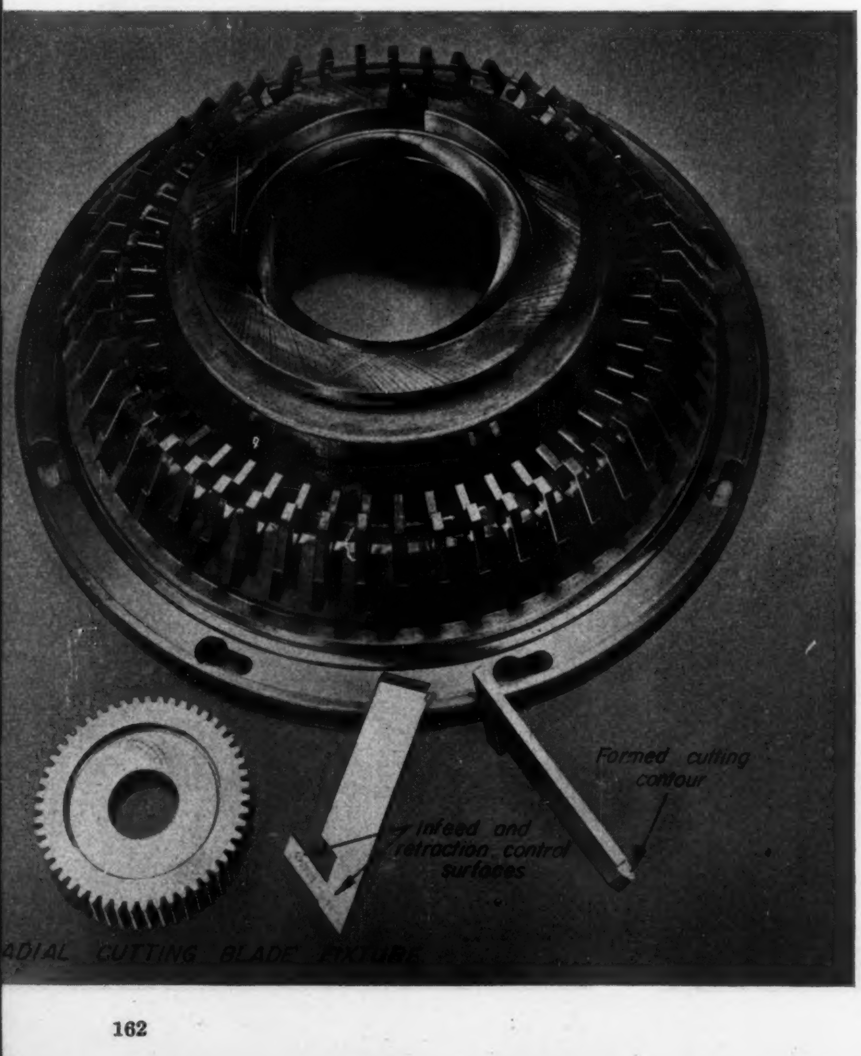
CUTTING all teeth or configurations simultaneously, the Shear-Speed external shaper, right, is used for producing gears, splines, sliding clutches, ratchets, etc. Its operating cycle is automatic. After the work is clamped hydraulically on the fixture, the head lowers to cutting position and hydraulically-actuated wedge pins lock it in place. Work is then reciprocated







SECTION THROUGH HYDRAULICALLY-ACTUATED WEDGE LOCKING PIN



ADIAL CUTTING BLADE FIXTURE

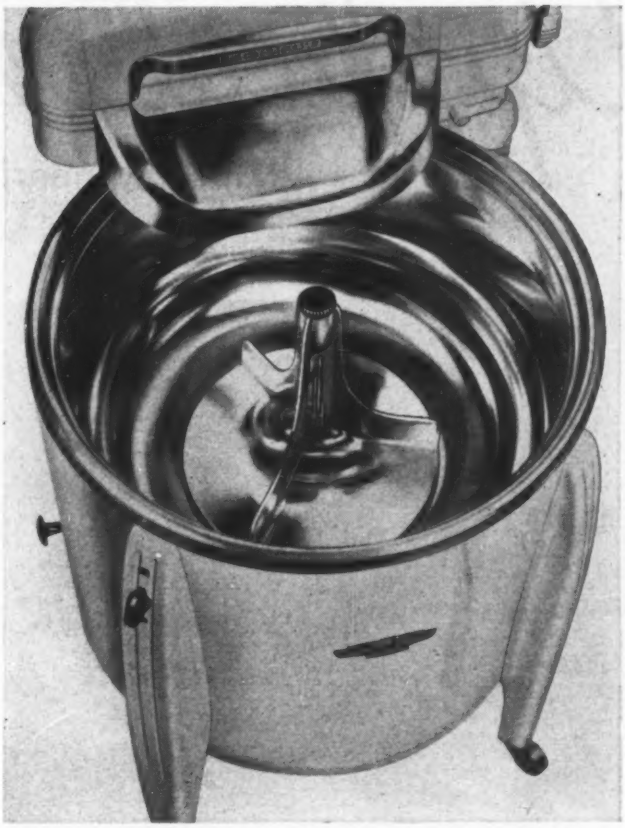
vertically through the cutting head, the cutting blades being fed radially at the start of each cutting stroke and retracted during each down stroke to provide clearance. Upon completion of the cutting cycle, the head is automatically unlocked and elevated, and the work is hydraulically released.

Mounted in the cutting head is a radial cutting-blade fixture. In this fixture, the blades are mounted radially in slots. The outer ends of the blades bear against the inner area of the outside cone of the head, and the inner cone of the head fits into the angular slots of the blades (see photos). The inner cone controls relief of the blades on the return stroke, while the outer cone controls feed of the blades on the cutting stroke.

Shown in the cross-section drawing, above, is one of the two hydraulically-actuated wedge locking pins which hold the head securely in place against a stop block during the cutting operation. Three interchangeable "slip-in" wedge blocks that mate with the wedge angle of the locking pins provide automatic vertical adjustment throughout the life of the cutting blades.

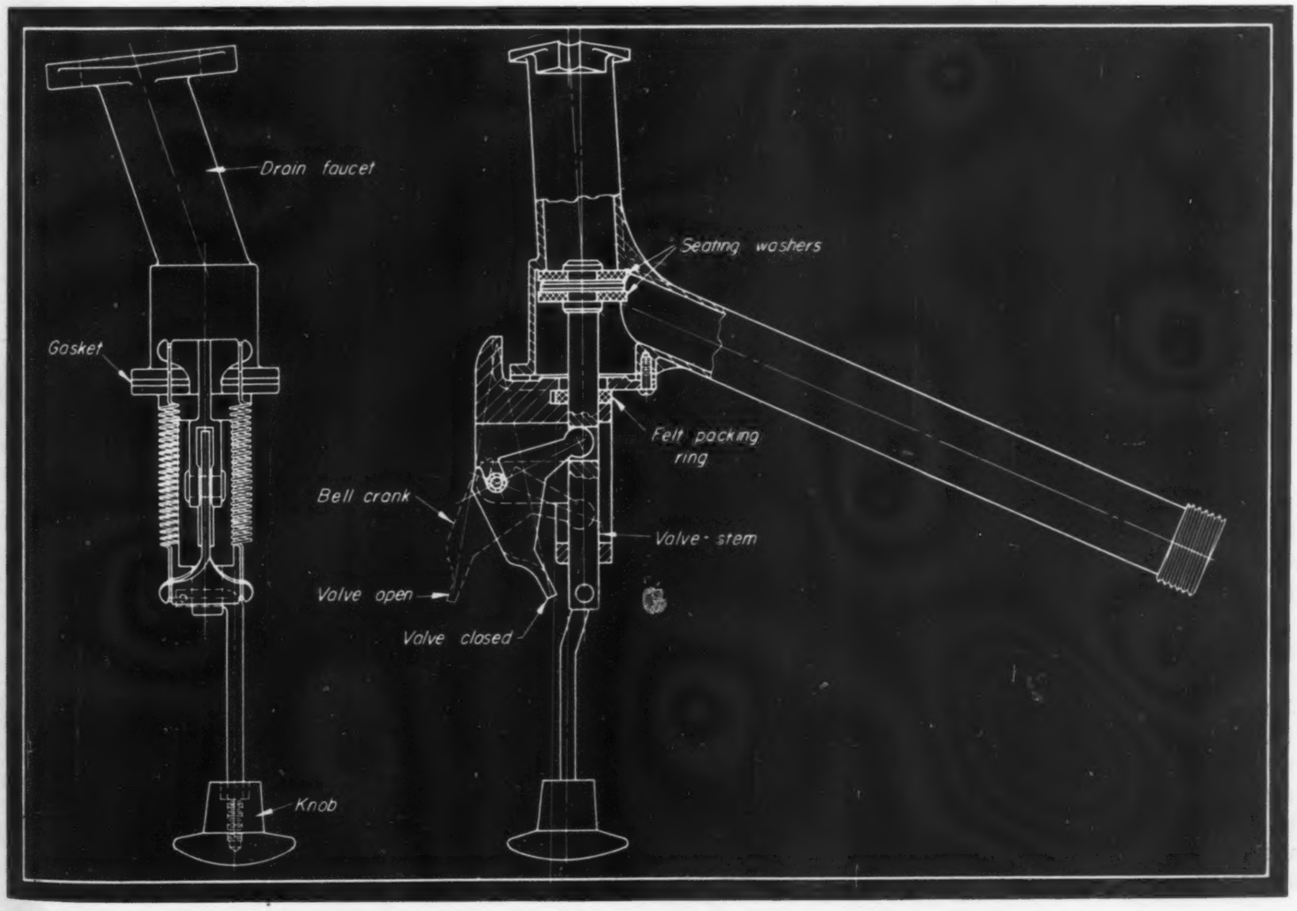
Main drive to all mechanical components plus the hydraulic pump is by multiple V-belt, while a separate motor drives the coolant pump which floods the work during each cutting cycle. Manufacturer: Michigan Tool Co., Detroit.

Toggle Positions Washer Drain Valve



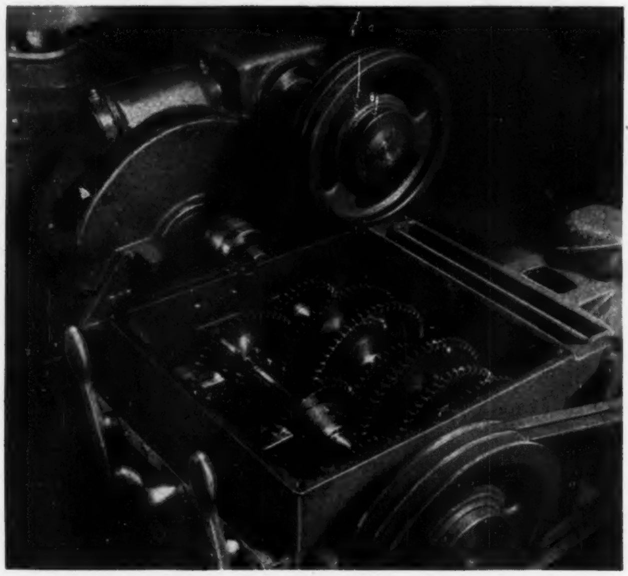
POSITIVE drain-valve positioning is effected in the Speed Queen clothes washer, by adaptation of the familar toggle principle. As is shown in the drawing, a spring-loaded bell crank is employed, one leg operating in a slot in the valve stem, while the other leg is notched to accommodate anchorage of two tension springs. The over-center or toggle action of the crank is such that at one end of its stroke it holds the valve closed under spring pressure, and at the other end of its stroke it holds the valve open under spring pressure. Actual opening and closing is effected manually by pushing or pulling the valve stem by means of the knob.

Two seating washers are employed on the valve stem. One of these seals the valve when closed, and the other prevents leakage past the stem when the valve is open. Felt packing around the stem acts as a wiper and thus offers added protection against corrosion. Replacement of the seating washers is readily accomplished by removing the two springs and three machine screws. The entire unit is inexpensive to produce because stampings and die castings are used throughout, holding machining to a minimum. Manufacturer: Barlow & Seelig Mfg. Co., Ripon, Wis.



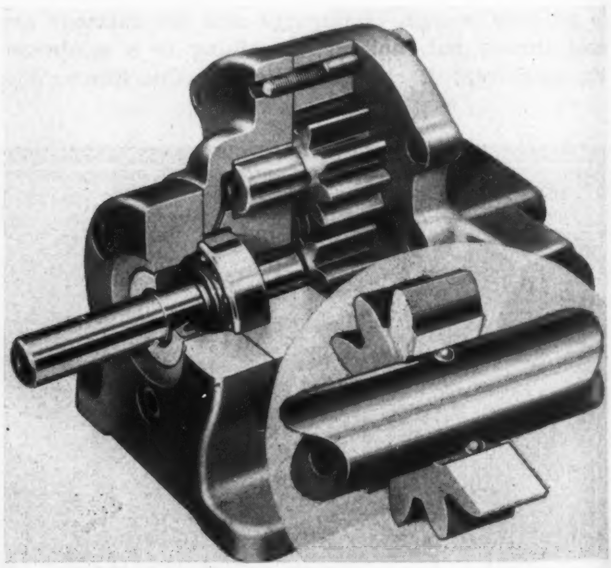
Applications

of engineering parts, materials and processes



Provides Gear Toughness

SMALL-PITCH Meehanite gears in the transmission of the Denver universal flame-hardening machine, left, have the body toughness and surface hardness needed to withstand the severe loading to which they are subjected in service. Machined from type GA castings and then flame hardened to 461 Brinell, the gears have been operated for over two years under severe impact loading—no clutch is used in the machines—without any sign of failure. Particularly unusual feature is this choice of material for such fine-tooth gears.

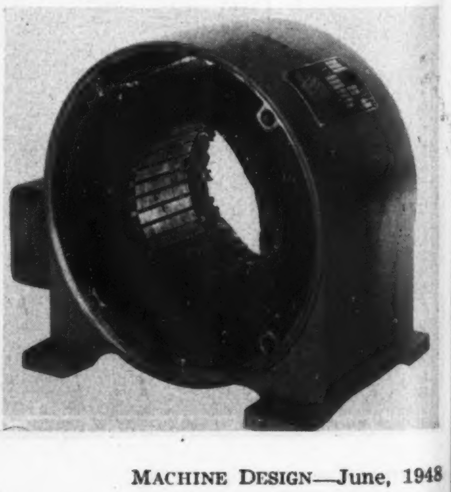


Pump Impeller "Floats"

KEYING method, right, used to attach impellers of the Adel hydraulic pump to driveshaft prevents thrust loads from being transferred from shaft to impeller or end plates. Key consists of balls placed in three grooves spaced around periphery of shaft and shaftway. Impellers are thus free to "float" in the pump cavity despite any lateral motion of shafts.

Has Aluminum Frame

LIGHT weight and high heat conductivity of aluminum were used to advantage by the designers of the Hertner induction motor. Frame and end bells, shown at right, as well as rotor are aluminum castings, the first time aluminum is believed to have been used for all structural parts of an integral-horsepower motor. Units up to 30 hp are so made with resultant weight reduction and cool operation.



Applying Planetary Gears to Differential Drives

BY using a differential drive the scope of application of variable-speed transmissions can be greatly extended. In such a drive the power from the prime mover divides into two paths, one of which usually is purely mechanical. The other path contains the variable-speed transmission which may be an electric motor-generator drive, a hydraulic torque converter, a positive-displacement hydraulic transmission, or a mechanical variable-speed transmission. The two power-flow paths join each other again at the output end.

One of the purposes of the differential drive is to permit reduction in the size of the variable-speed unit by reducing the power which it must transmit to a fraction of the total power. The differential drive also can be employed to secure extremely close regulation of output speed.

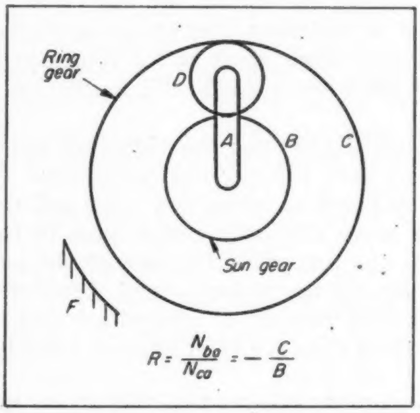


Fig. 1—Simple internal-external planetary unit. Speed relationships between the elements A, B and C are given by Equations 1, 2 and 3. Replacement of planet pinion D by any of a variety of gear trains will not alter these basic relationships but will alter the numerical value and sign of ratio R

Application of a differential drive is full of traps for the unwary. This is because the double power-flow path is capable, under certain conditions, of transmitting power in the wrong direction. When this happens the other path is overloaded and there may result a serious loss of efficiency. A drive in which this condition occurs is known as a "regenerative system." Although regenerative hook-ups should be avoided when a nonregenerative system will do, they do make possible large reductions in small space with few gears. When properly analyzed and designed, regenerative systems have some justifiable use.

To assist designers in analyzing differential drives this Data Sheet has been prepared as a sequel to "Planetary Gear Calculations" (M.D., March, 1948. page 165). As there pointed out, calculations of speed ratios are difficult to check by common-sense observation. This is true to an even greater extent in calculating torques in differential circuits. Numerically the computations are extremely simple, and if sign conventions are rigidly observed the formulas here presented will permit the designer to make a fairly extensive exploration of the various possible arrangements in a short time.

Heart of the differential drive is the planetary gear train. It is therefore necessary to have a complete set of formulas relating the speeds and torques in such a unit. Speed relationships are fully covered in the Data Sheet which appeared in March, 1948. Using the same notation but dropping the subscript $_f$, since all calculations in what follows will be based on absolute speeds, speeds of the three elements of a planetary unit (one planet arm and two sun or ring gears) are related as follows (see *Fig.* 1):

$$N_a = \frac{N_b - RN_c}{1 - R} \qquad (1)$$

$$N_b = (1 - R)\,N_a + RN_c \qquad (2)$$

$$N_c = \frac{N_b - (1 - R)\,N_a}{R} \qquad (3)$$

where N_a = Speed of planet arm A (rpm)
N_b = Speed of sun or ring gear B (rpm)
N_c = Speed of sun or ring gear C (rpm)
R = Speed ratio (N_{ba}/N_{ca}) or speed of B to speed of C referred to arm A.

Values of the speed ratio R are easily derived in

This data sheet is based on information furnished by A. Y. Dodge, A. Y. Dodge Co., Rockford, Ill.

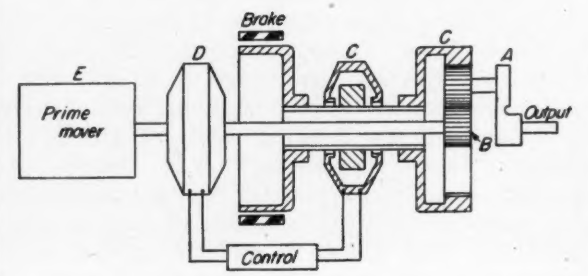
Engineering Data Sheet

terms of numbers of teeth in the gears. Examples for several of the more common types of planetary units are given in the March, 1948, Data Sheet.

Torque relationships depend on balancing the torque input and output. For a three-element unit the algebraic sum of the external torques acting on the unit must be zero:

$$T_a + T_b + T_c = 0 \qquad (4)$$

Another torque relationship results from the equilibrium between the two sun or ring gears B and C, the torque ratio between B and C being inversely proportional to the speed ratio R. If the ratio R is positive (both gears rotating in the same direction relative to the arm) the external torques applied will be opposite in sign, hence the torque ratio is written



$$N_c = \frac{N_e - (1 - R)\,N_a}{R}$$

$$T_b = \frac{T_e}{1 - \dfrac{R}{e} \times \dfrac{N_c}{N_e}}$$

$$T_c = -\,RT_b$$

$$T_a = (R - 1)\,T_b$$

Fig. 2—Differential drive in which power divides between a straight mechanical path to the sun gear B, and a branch through a torque converter D-C

$$\frac{T_c}{T_b} = -\,R \qquad (5)$$

In applying this relationship the proper sign must be assigned to the numerical value of R, just as in dealing with speed ratios. Thus, in *Fig.* 1 R is negative so the torque ratio would be positive.

Equations 4 and 5 may be combined to give the necessary formulas relating torques, as follows:

$$T_a = (R - 1)\,T_b \qquad (6)$$

$$T_a = \frac{(1 - R)}{R}\,T_c \qquad (7)$$

$$T_b = -\,\frac{T_c}{R} \qquad (8)$$

$$T_b = \frac{T_a}{R - 1} \qquad (9)$$

$$T_c = -\,RT_b \qquad (10)$$

$$T_c = \frac{R}{1 - R}\,T_a \qquad (11)$$

Equations 1, 2, 3, 6, 7, 8, 9, 10, and 11 furnish the basic relationships needed in analyzing a differential drive.

Schematic arrangement of one type of differential drive is shown in *Fig.* 2. A prime mover E (an engine or electric motor) drives sun gear B of a planetary unit direct. Ring gear C of the same unit is driven by a hollow shaft carrying one element of a variable-speed transmission. The other element of the variable-speed transmission is attached to the prime-mover shaft. For clarity the connection between the two variable-speed elements is shown as an electrical one, with a control unit permitting any desired speed ratio in either direction as well as power flow in either direction. The electrical drive could, with certain limitations, be replaced by any of a variety of mechanical or hydraulic variable-speed transmissions. A brake on the same shaft as the ring gear C is provided for use when a fixed-ratio mechanical drive is desired.

For practical purposes the planetary unit may be assumed to have 100 per cent efficiency. However, the variable-speed or torque converter unit will usually have a lower efficiency, which must be taken into account in the analysis. Purpose of the analysis is to determine the speed, torque and horsepower transmitted by each element at several selected speed ratios, providing data for the design or selection of the unit.

Torque analysis may be based on either the output torque or input torque, one of which must be assumed. Sometimes it is more convenient to assume the output torque and work back, inasmuch as there is only one output from the planetary unit but two inputs to it. However, if efficiency of the torque converter unit must be considered, it may be just as simple to calculate all torques as percentages of the input torque at the prime mover. By simple proportion the torques can later be expressed in terms of the output torque, if desired.

Considering the system shown in *Fig.* 2, the power delivered to gear C by the torque converter D-C is less than the power taken off the shaft at D, the relation being

$$N_c T_c = e N_d T_d \qquad (12)$$

If the conditions of operation should be such that power flows in the opposite direction, the efficiency factor should, of course, be transferred to the opposite side of the equation

$$eN_cT_c = N_dT_d \quad \text{(12a)}$$

In order to solve for the unknown torques, one more relationship is required. The input torque is the sum of the torques leaving the input shaft at D and at B or

$$T_e = T_d + T_b \quad \text{(13)}$$

Substituting for T_c from Equation 10 and for T_d from Equation 12, Equation 13 becomes

$$-N_cRT_b = eN_dT_e - eN_dT_b$$

Solving for T_b and noting that $N_d = N_e$

$$T_b = \frac{T_e}{1 - \frac{R}{e} \times \frac{N_c}{N_e}} \quad \text{(14)}$$

Other torques may be found from Equations 6, 10, and 13. The necessary formulas are summarized in *Fig.* 2. If it is found that power flows backward through *C-D*, the term e in Equation 14 should be replaced by the reciprocal of the efficiency.

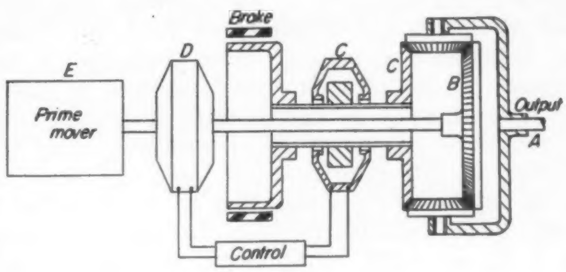
A special case of *Fig.* 2 is shown in *Fig.* 3, in which a bevel gear differential, for which $R = -1$, is used.

By transposing the elements of the planetary unit, the arrangement shown in *Fig.* 4 results. By similar process of analysis the equations shown on the figure may be developed. These are on the basis of power flow from D to A through the torque converter, and again the reciprocal of efficiency must be used if power flows in the opposite direction.

Power transmitted through each branch is the product of torque and speed, in calculating which the proper signs must be retained. If power through a branch is negative, this means that the system is regenerative, and it will be found in such cases that power flow in the other branch is greater than the total.

EXAMPLE 1: To illustrate the foregoing analysis

ENGINEERING DATA SHEET



$$N_c = 2N_a - N_e$$

$$T_b = \frac{T_e}{1 + \frac{1}{e} \times \frac{N_c}{N_e}}$$

$$T_c = T_b$$

$$T_a = -2\,T_b$$

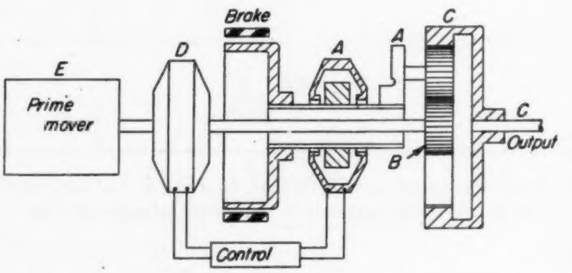
Fig. 3—Differential drive similar to Fig. 2 but employing bevel gear differential in place of planetary unit

TABLE I--Relative speeds, torques and horsepowers of differential drive, Fig. 3

Speeds % of Input		Torques % of Input			Power % of Input			Class of Drive
N_a	N_e	$T_b=T_c$	$T_d=T_e-T_b$	Ta	P_b	P_e	Total	
200	300	25.0	75.0	—50.0	25.0	75.0	100.0	Nonregenerative
150	200	33.3	66.7	—66.7	33.3	66.7	100.0	Overdrive
100	100	50.0	50.0	—100.0	50.0	50.0	100.0	
90	80	55.5	44.5	—111.1	55.5	44.5	100.0	Nonregenerative
80	60	62.5	37.5	—125.0	62.5	37.5	100.0	Reduction
70	40	71.4	28.6	—141.8	71.4	28.6	100.0	Drive
60	20	83.3	16.7	—166.7	83.3	16.7	100.0	
50	0	100.0	0	—200.0	100.0	0	100.0	Mechanical
40	—20	125.0	—25.0	—250.0	125.0	—25.0	150.0	
30	—40	166.7	—66.7	—333.3	166.7	—66.7	233.4	Regenerative
20	—60	250.0	—150.0	—500.0	250.0	—150.0	400.0	Reduction
10	—80	500.0	—400.0	—1000.0	500.0	—400.0	900.0	Drive
0	—100	∞	∞	∞	∞	∞	∞	
—10	—120	—500.0	600.0	1000.0	—500.0	600.0	1100.0	
—20	—140	—250.0	350.0	500.0	—250.0	350.0	600.0	Regenerative
—40	—180	—125.0	225.0	250.0	—125.0	225.0	350.0	Reverse
—60	—220	—83.3	183.3	166.7	—83.3	183.3	266.6	Reduction
—80	—260	—62.5	162.5	125.0	—62.5	162.5	225.0	Drive
—100	—300	—50.0	150.0	100.0	—50.0	150.0	200.0	

Engineering Data Sheet

with respect to *Fig.* 2, consider a system with a planetary unit having $R = -2$ operating with input speed $N_e = 100$ and output speed $N_a = 50$. Under this condition the gear *C*, from Equation 3, has a speed of 25. The torque converter is therefore operating at a speed ratio $N_c/N_d = 0.25$ (a reduction of 4 to 1). Assuming that its efficiency at this point is 75 per cent, the torque T_b can be calculated from Equation 14 and is found to be 60. From Equation 10, $T_c = 120$ and from Equation 6, $T_a = -180$. (The minus sign merely indicates that external torque applied at the output end



$$N_a = \frac{N_e - RN_c}{1 - R}$$

$$T_b = \frac{T_e}{1 + \dfrac{R-1}{e} \times \dfrac{N_a}{N_e}}$$

$$T_c = -RT_b$$

$$T_a = (R - 1)\,T_b$$

Fig. 4—Another type of differential drive, employing the same elements as in Fig. 3 in a different arrangement

is opposite to that applied at the input end.) If the efficiency had been 100 per cent, the output torque would have been -200, hence the actual overall efficiency is 90 per cent. This demonstrates that the differential drive makes possible a higher overall efficiency (90 per cent) than is attained by the torque converter itself (75 per cent).

EXAMPLE 2: To show how a regenerative system gives a different result, consider a similar system in which the only change is the addition of an idler pinion in the planetary unit, making the value of *R* $= +2$ instead of -2. For the same speed ratio ($N_e = 100$ and $N_a = 50$) the speed of N_c is now 75, and the torque converter is operating at a speed ratio of 0.75. Assuming the same efficiency as before (75 per cent) the torque T_b (from Equation 14) is found to be -100, $T_c = +200$ and $T_a = -100$. Inasmuch as the output torque would have been -200 with 100 per cent efficiency, the actual efficiency of this regenerative system is only 50 per cent. This is because the torque converter unit takes out more torque than the prime mover supplies ($T_d = T_e - T_b = 100 - -100 = 200$) but transmits it to *C* at only 75 per cent efficiency. Because twice as much power is transmitted with 25 per cent loss, the overall loss is 50 per cent of the total power.

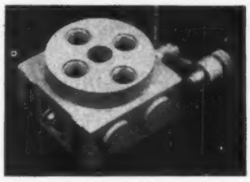
EXAMPLE 3: Another example of a regenerative system results when the system of *Fig.* 4 is used to transmit a considerable speed reduction with speed reversal. Thus, if $R = -2$, $N_e = 100$ and $N_c = -20$, (the minus sign indicating a reversing drive) with a torque converter efficiency 75 per cent, the equations in *Fig.* 4 show that $N_a = +20$, $T_b = 500$, $T_c = 1000$, $T_a = -1500$, for $T_e = 100$. Critical examination of these figures reveals an absurdity. With a speed change from 100 to -20 the output torque T_e would be only 500 with 100 per cent torque converter efficiency. To make possible the result obtained, power would have to be added somewhere. The proper interpretation of the foregoing result is, of course, that power is actually flowing backward through the torque converter, and the efficiency *e* in the equation for T_b in *Fig.* 4 should be replaced by the reciprocal of efficiency. When this is done the torque values become $T_b = 182$, $T_c = 364$, and $T_a = -546$. The overall efficiency is therefore $364/500 = 0.728$ or 72.8 per cent, only slightly less than the torque converter efficiency. This is because the backward power flow through the torque converter ($N_aT_a = 20 \times -546 = -10{,}920$) is only slightly greater than the input ($100 \times 100 = 10{,}000$).

To show how a drive may be made to function either regeneratively or nonregeneratively, depending upon the overall speed ratio, TABLE I has been prepared for the simplified case of *Fig.* 3 with 100 per cent torque converter efficiency. It will be observed that in all cases the *net* power output $P_b + P_c$ is equal to 100 per cent of the input, but the *total* power transmitted through the differential may be many times this amount when the drive is operating regeneratively. For example, at an output speed N_a equal to 10 per cent of input, 500 per cent of input power enters the differential unit through the sun gear *B*. Of this, 100 leaves the unit through the carrier to the output shaft *A* and the remaining 400 goes back into the drive through bevel gear *C* and the torque converter. This is sometimes referred to as "circulating horsepower"; it overloads the drive elements and has been known to cause serious failure.

new parts and materials

For additional information on these new developments see Page 279

Four-Way Selector Valve



Cam - operated selector valve provides a simple means of controlling flow to remote actuating cylinders of hydraulic systems. Light and compact, the valve consists of aluminum - alloy body which houses spring-loaded balanced type poppet valves, interconnected by ducts. Rotation of camshaft, opens proper combination of poppets to direct the fluid to desired location. Manufacturer: Electrol Inc., Kingston, N. Y.

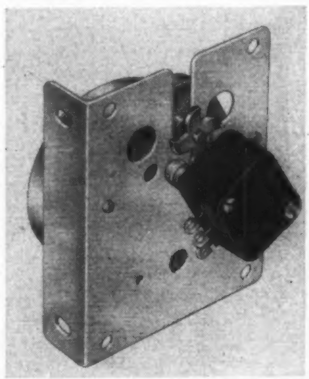
For further information circle MD 1 on Page 279

Thin Ball Bearings

Having a cross-sectional area as much as 66 per cent smaller than that of conventional bearings of equal sizes, XLS series are light and compact and capable of taking thrust in either direction. They are made in sizes from 1⅜-inch to 10-inch bore with outside diameters ranging from 2 9/16 inches to 13¼ inches. Applications include thin wall housings and other uses where space is at a premium. Manufacturer: The Federal Bearings Co., Inc., Poughkeepsie, N. Y.

For further information circle MD 2 on Page 279

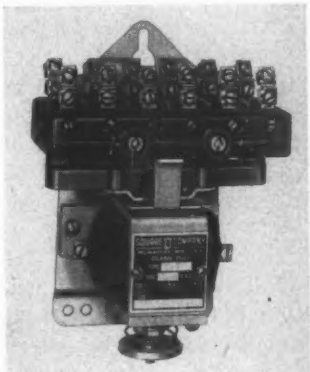
Flash Timers



Interrupter or flash timers will produce up to 72 low - current pulses per minute. They are recommended for use in electronic heating circuits or other circuits requiring repeated pulses of constant and predetermined accuracy. Known as series No. 5400, the timers measure 3 by 2 5/16 by 2⅛ inches. They consist of a series 1600 timer together with a 4-lobe cam and a miniature snap switch rated 5 amperes at 125 volts a-c. Accuracy of the assembly is plus or minus 20 per cent of the time cycle. Range is from 72 pulses per minute (each 0.4-second) to 1 pulse every 2 minutes (each 1 minute in duration) . Typical intermediate flash rates are 60, 40, 30, 20, 10, 5, 3, 2 and 1 pulse per minute. Manufacturer: Haydon Mfg. Co. Inc., 245 E. Elm St., Torrington, Conn.

For further information circle MD 3 on Page 279

Magnetic Multipole Relays



Two new d-c magnetic multipole relays have been added to the Square D line of controls. Designated types Q and R, the relays are similar in features and characteristics to the a-c multipole contactors made by the same manufacturer. They are suitable for operation on voltages up to 250 and utilize double - break silver-to-silver contacts which are readily converted from normally-open to normally-closed without additional parts. The relays are steel-panel mounted and insulated to permit direct mounting on grounded metal panels. All terminals are accessible from the front and are equipped with two wiring clips to accommodate the multiple connections. Type Q is available with from 2 to 6 poles. Type R, a heavier relay, is available with from 2 to 5 poles in any combination of normally-open and closed circuits. Manufacturer: Industrial controller division, Square D Co., 4041 N. Richards St., Milwaukee 12.

For further information circle MD 4 on Page 279

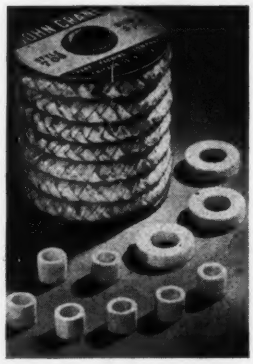
Electronic Amplidyne

Consisting of a high-gain balanced d-c electronic amplifier and a motor amplidyne, new unit is useful in many types of motor control where precise regulation of current, voltage and speed is necessary. The unit is designed for use as a regulated, adjustable-voltage power supply for d-c motors up to 1½ hp and as a regulated exciter for larger adjustable-voltage drives up to 200

hp. It has an output of 1½ kw, at 250 volts and is arranged for use on either a 220 or 440 volt, 3-phase, 60-cycle supply. Making possible a speed range of 20 to 1 or greater, the amplidyne maintains speed closely at any setting regardless of load conditions, assuring smooth rapid acceleration and reducing starting shock on the driven machine. Manufacturer: General Electric Co., Schenectady 5, N. Y.

For further information circle MD 5 on Page 279

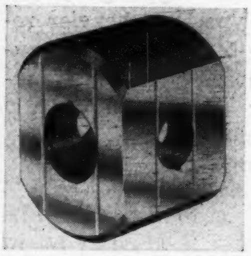
Teflon Packing for Shafts



Chemlon line of shaft packing is made of Teflon and will withstand acid and caustics to almost 700 F. Wear of shafts is reduced by the nonadhesive characteristics of the Teflon. The material is available in several forms: Style 706 is a braided packing furnished in sizes from ⅛ to 1 inch diameters. It is treated with a special chemically resistant lubricant that in itself is unaffected by acids or caustics to 300 F. Style 704, made in the same sizes, has no added lubricant and is specified for temperatures in excess of 300 F. Two styles of ring packing are made: Types 772 and 776. 772 contains no lubricant and 776 is impregnated with graphite throughout its fibrous structure. Manufacturer: Crane Packing Co., 1800 Cuyler Ave., Chicago 13.

For further information circle MD 6 on Page 279

Improved Universal Joint



Heat generation has been greatly reduced in Curtis line of universal joints ranging in size from ¼ to 4 inches. Center block now used has shallow grooves on each of its four bearing surfaces, dividing each surface into four areas. By reducing the size of the areas subject to friction, a more even distribution of lubricant, and therefore of wear, is experienced. As a result, joints have reduced failure at excessive torque or transmission angle. Manufacturer: Curtis Universal Joint Co. Inc., Springfield, Mass.

For further information circle MD 7 on Page 279

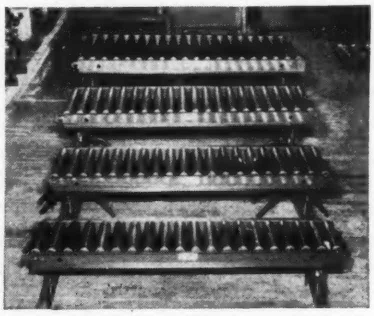
Coolant Pumps

Two new coolant pumps have been added to the Allis-Chalmers Norwood line of pumps. Designed for general circulation duty, the pumps are of the low-head, single-stage, close-coupled type. One is vertical and operates submerged; the other is a side-wall mounted unit. The submerged pump, known as type KF, is designed for use on machines requiring a large coolant tank. Having no stuffing box, the pump is especially suitable for handling liquids containing large amounts of solids, chips or suspended abrasive particles. The side-wall mounted pump, also designed for handling gritty and abrasive materials in suspension, is known as type KW. It is available with two different length adapters depending on the depth of the coolant reservoir. Impellers of both pumps are of cast, corrosion-resistant, zinc-free bronze. Both units are made in ¼ to 1-hp sizes and will operate against 10 to 70-ft heads. Manufacturer: Allis-Chalmers Mfg. Co., Milwaukee 1.

For further information circle MD 8 on Page 279

Roller Gravity Conveyor

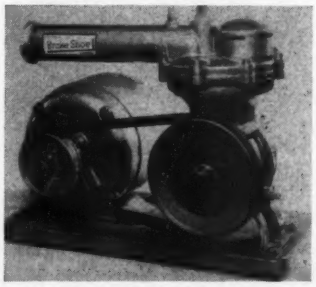
Two new widths have been added to the line of Rapid-Roller gravity conveyors. Supplementing the original widths of 12 and 18 inches, the new widths of 15 and 24 inches are also manufactured in either



5 or 10-foot lengths. The conveyor channel is 3½ inches deep and 1 inch wide and is reinforced with cross angles. Rollers are 2 inches in diameter and are formed of 16-gage steel. Manufacturer: Rapids-Standard Co. Inc., Dept. RR-139, 342 Rapistan Bldg., Grand Rapids 2, Mich.

For further information circle MD 9 on Page 279

Diaphragm Type Air Compressors



Particularly suitable for low-pressure, high-volume applications, two new fractional-horsepower diaphragm type air compressors deliver 100 per cent oil-free air. Model 17-C delivers 4.4 cfm at 40 psi. Powered with a ½-hp motor it utilizes permanently lubricated sealed ball bearings and has twin air cleaners. Particular feature of this model is use of welded-steel frame to provide stability. Model 8-C delivers 2.2 cfm at 25 psi and is powered by a

JOHNSON BRONZE

Sleeve Bearings

FROM coast to coast these twenty Johnson Bronze warehouses make available standard sleeve bearings in a full range of sizes. They stock General Purpose Bronze Bearings, Electric Motor Bearings, Automotive Bearings and Bushings, and Universal Bronze Bars. In addition, industrial supply distributors, electric motor distributors, and automotive jobbers maintain large stocks of Johnson Bronze bearings in all principal cities.

For special sleeve bearings or blueprint requirements, you may call in the Johnson Bronze district manager who is located in your locality.

Thus . . . you are assured prompt bearing service wherever you are located . . . whatever you need.

JOHNSON BRONZE COMPANY
525 SOUTH MILL ST. NEW CASTLE, PA.

Johnson Bronze Sleeve Bearings Give You Every Worthwhile Advantage

- LOW COST
- PRECISION
- QUIET
- LONG LIFE
- CORROSION RESISTANT
- UNIT CONSTRUCTION
- LOAD CARRYING CAPACITY
- HIGH RESISTANCE TO SHOCK
- LOW COEFFICIENT OF FRICTION
- EASY TO INSTALL
- CONFORMABILITY
- NATION WIDE SERVICE

JOHNSON BRONZE
SLEEVE BEARING HEADQUARTERS

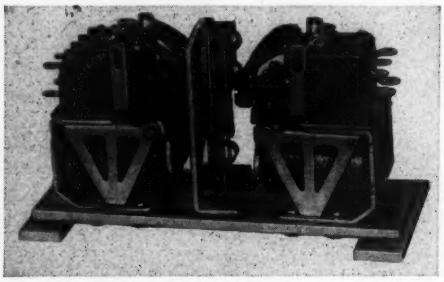
BRANCHES IN 20 INDUSTRIAL CENTERS

$\frac{1}{4}$-hp motor. Equipped with a single air cleaner, the model has force-feed oil system, assuring positive lubrication. Manufacturer: Kellogg Div., American Brake Shoe Co., 97 Humbolt St., Rochester 9, N. Y.

For further information circle MD 10 on Page 279

Memory Relay

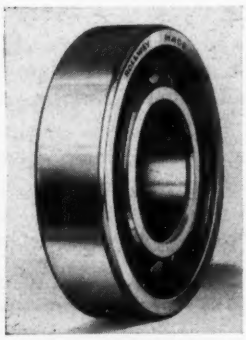
Consisting of two mechanically interlocked relays and a single-pole snap switch operated by an interlocking bar, Phil-trol relay No. 27-27 serves as a



safety device. Switch will remain in position if only one relay is operated, or if the relay is de-energized and re-operated. Only when the second relay is energized will the snap switch return to its first position. The unit is made for use with all d-c voltages up to 230 and may have from 1 to 5 poles in single or double-throw combinations. Contact capacity is either 10 or 20 amperes; dimensions are $4\frac{3}{8}$ inches long, $2\frac{1}{2}$ inches wide and $2\frac{3}{8}$ inches high. Manufacturer: Phillips Control Corp., 612 N. Michigan Ave., Chicago 11.

For further information circle MD 11 on Page 279

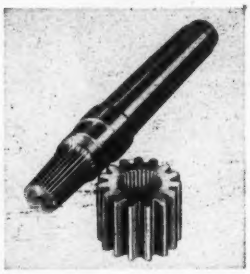
Cylindrical Roller Bearings



Featuring the use of a one-piece steel retainer, Tru-Rol bearings are said to achieve long life because of the roller alignment assured by the deep, broad double flanges of the retainer. The new line of bearings are manufactured in a range of sizes conforming with SAE standards; BE-1200 and BE-1300 series corresponding to the single row type of the 200 and 300 sizes, respectively. The BE-5200 series corresponds to the wide type. Additional feature of the bearings is the use of deep ring grooves in the inside of the outer race, snap rings, engaging the groove hold the assembly in place. All bearings in the line can be applied with or without the inner race. Manufacturer: Rollway Bearing Co. Inc., 541 Seymour St., Syracuse 4, N. Y.

For further information circle MD 12 on Page 279

Serrated Shafts and Pinions

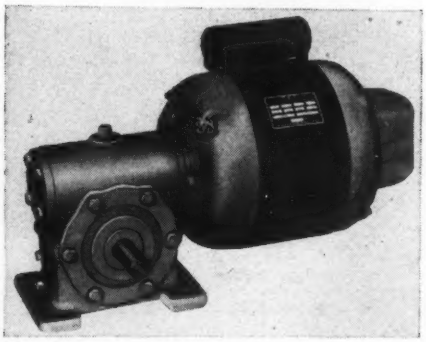


Tapered serrated gear and pinion sets are designed to provide high strength and long life. Need for keys is eliminated and strength is increased up to 50 per cent over conventional joints. Available in a wide range of standard sizes, the shafts and pinions can also be specially designed to meet special requirements. Manufacturer: Pittsburgh Gear Co., 27th and Smallman Sts., Pittsburgh 22.

For further information circle MD 13 on Page 279

Single-Phase Gearmotors

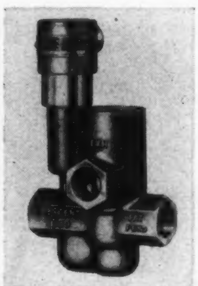
Four sizes—1/6, 1/4, 1/3 and 1/2-hp—comprise the TEC line of gear motors. Made in output speeds ranging from 16 to 340 rpm, the motors will operate on either single or three-phase power. Features of the units include new design which obviates need for brushes or centrifugal switches. Motors have steel



frames with magnesium end bells; gear housings are heavy cast iron. Manufacturer: Triad Engineering Corp., 2414 S. LaSalle St., Chicago 16.

For further information circle MD 14 on Page 279

Pilot-Actuated Solenoid-Controlled Valve



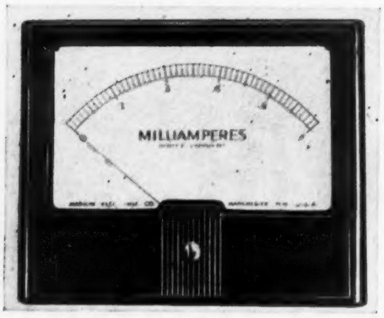
Fast-acting, pilot-actuated solenoid-controlled, three-way valve is suitable for use with air, water, and light oils. The new unit, designated model 1030 is available for pressures from 25 to 140 psi and is made in either normally-open or normally-closed types. It is of cast-bronze construction with stainless ball valves arranged between bronze seats. Conversion to straight shut-off operation can be made by merely plugging the exhaust port. Standard sizes range from $\frac{1}{4}$-inch to $1\frac{1}{4}$ inch; the $\frac{3}{4}$-inch

size, for example, weighs 5½ pounds and measures 2¼ by 4¼ by 7½ inches. All valves in the line are supplied with screw-in type solenoids which are available to operate on any standard voltage either a-c or d-c. Manufacturer: Crescent Valve Co., 6073 State St., Huntington Park, Calif.

For further information circle MD 15 on Page 279

Large Dial Electric Meters

Featuring 100-degree scale arc and 5½-inch scale length, model 56 ammeter fills the gap between 4½ and 8-inch meters. Instrument measures 6½ by 5¼

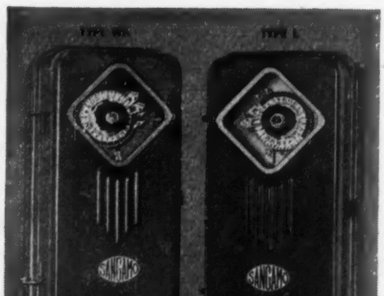


inches, has Bakelite case, and uses Alnico magnets for all current ranges. Manufacturer: Marion Electric Instrument Co., Manchester, New Hampshire.

For further information circle MD 16 on Page 279

Heavy-Duty Time Switches

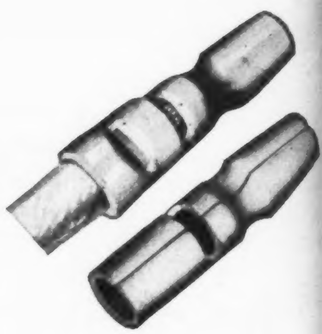
Several major improvements have been made in the Sangamo line of heavy-duty time switches. They are now each equipped with a fully-encosed hysteresis-



synchronous low-speed motor, providing high starting and operating torque. New replaceable bearing system is lubricated with a special silicone product, preventing it from being affected by temperature and the motor is housed in a molded shell to protect the insulation. A closer time limit between settings is possible with the new timers, permitting a wider range of applications, the minimum time between setting of the off and on periods being 90 minutes. Time interval between on and off periods is 30 minutes. Manual tripping can be done at any time without disturbing the automatic operation. Manufacturer: Sangamo Electric Co., Springfield, Ill.

For further information circle MD 17 on Page 279

Plug-Type Terminal



Providing easy, convenient method of installing connections on leads of electrical apparatus, plug type terminal known as Shur-Plug is suitable for use with 16-14 wire size. Crimped type connection has high electrical conductivity and corrosion resistance. The fittings are suitable for stranded wire and are designed to make perfect plug-in connections with standard female fittings. Manufacturer: Aircraft-Marine Products Inc., 1580 N. 4th St., Harrisburg, Pa.

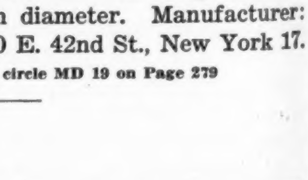
For further information circle MD 18 on Page 279

Polished Sapphire Balls

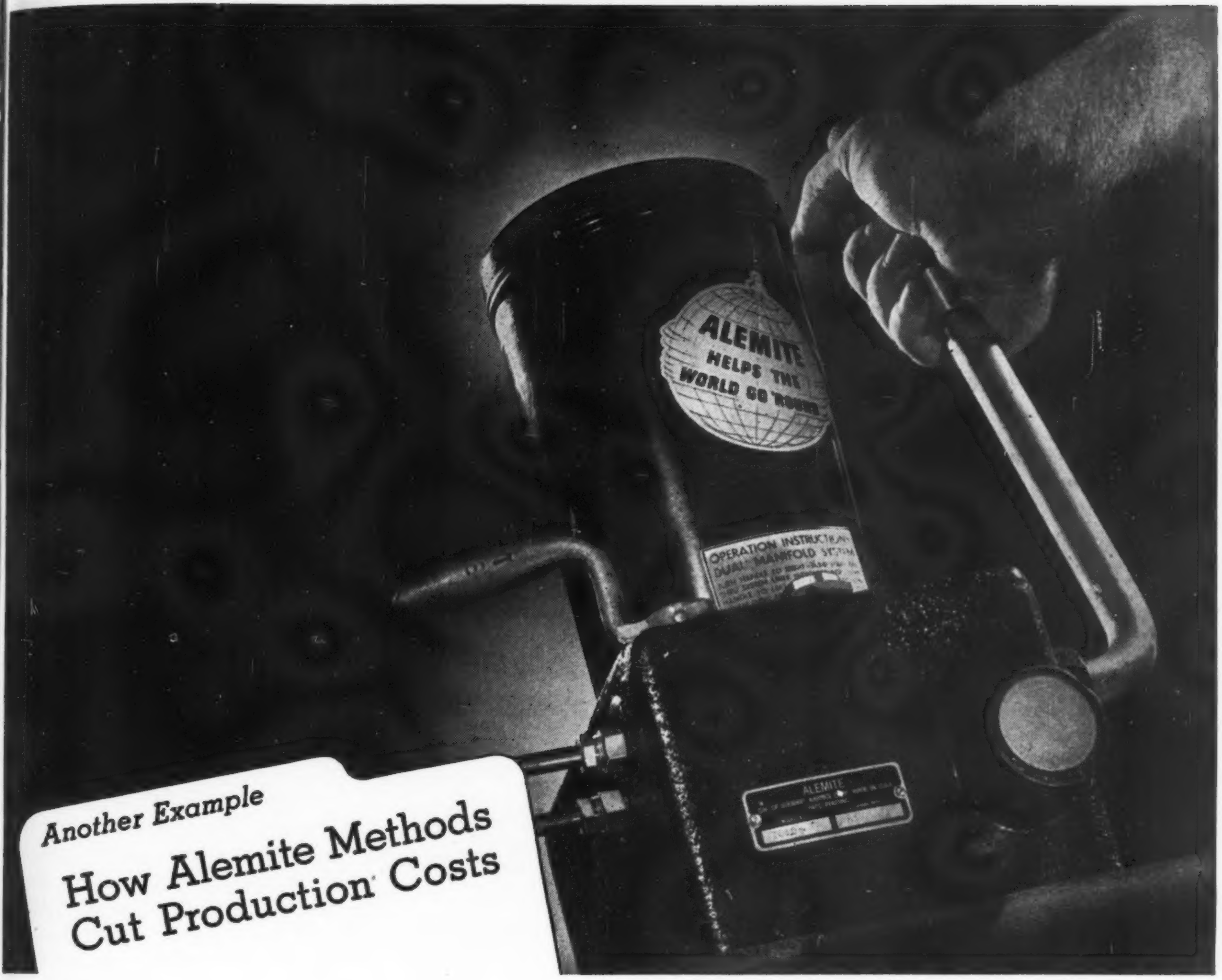
Polished synthetic sapphire balls, ground to an accuracy of 0.000010-inch, are homogeneous and not subject to stress concentration owing to surface defects or to creep phenomena. Recommended for high temperature bearing applications or use under corrosive conditions, they need no lubrication. Clear sapphire balls are available in the following sizes: 1 mm; 1/16, ⅛ and ¼-inch diameter. Manufacturer: Linde Air Products Co., 30 E. 42nd St., New York 17.

For further information circle MD 19 on Page 279

Interlock Door Switch



Designed for use on the types of apparatus where electrical circuits, etc., might be dangerous to the operating or maintenance personnel, the interlock door switch cuts off power circuit when the cabinet door is opened. The service personnel can, however, close the circuit for checking by manually moving the actuator. The design eliminates the hazard of forgetting to reposi-



Reduces 182 Lubrication Points to One!

Adds Productive Time to Machines with Faster, More Efficient Handling and Application of Lubricants

Protect Those Machines You Design from Human Error

Human error in lubrication can easily destroy the efficiency of the best designed machine. A five minute conference with an Alemite Representative may well reveal modern features that make lubrication foolproof. This man is fully qualified to help you because he is a specialist in modern methods of handling and applying lubricants. Write to Alemite, 1804 Diversey Parkway, Chicago 14, Illinois.

Whether it's only one hard to reach bearing on a machine or 182 lubrication points on another, they can all be perfectly lubricated by this modern Alemite Method. With one hand, and a few strokes on a handle, any bearing, no matter how remote, is lubricated completely in seconds from one safe, central point while the machine keeps on producing!

An Alemite Centralized Lubrication System eliminates "human error," adds more productive time to any machine. It delivers a measured amount of lubricant to each bearing, then signals when the job is completed. Result—no costly bearing failures due to hit-or-miss, feast-or-famine lubrication.

Just one of many ways that Alemite Methods help industry cut production costs through simplified lubrication procedures. And the Alemite Representative can show case after case where a time study analysis has proved that his methods reduce maintenance costs. These methods eliminate costly, time-consuming handling of oils and greases ... slash shutdown time for lubrication ... completely mechanize lubrication from barrel-to-bearing ... save grease ... keep dirt and moisture out of lubricants. These benefits all add up to lower production costs and longer machinery life. Get the complete facts, today.

ALEMITE

REG. U. S. PAT. OFF.

Another Product of STEWART WARNER

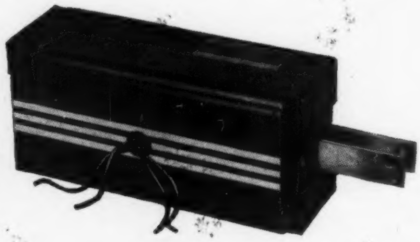
MODERN LUBRICATION METHODS THAT CUT PRODUCTION COSTS

tion the switch to the safe position, since closing the door returns the actuator to normal position. Provision is made for mounting on two faces, and the actuator rod has a deep threaded hole for acceptance of an adjustable-length actuator pin or button. The switch, type 1AC1, is a single-pole double-throw unit rated 10 amperes at 125 volts a-c. Manufacturer: Micro Switch, Freeport, Ill.

For further information circle MD 20 on Page 279

Reciprocating Solenoids

Consisting of two solenoids mounted in tandem, the RD 325 solenoid operates through a common plunger. The individual solenoids operate one at a time, the plunger moving in one direction and being held there until the solenoid becomes de-energized. Units are made in two types, two position and the three position. In the former, the plunger can be in

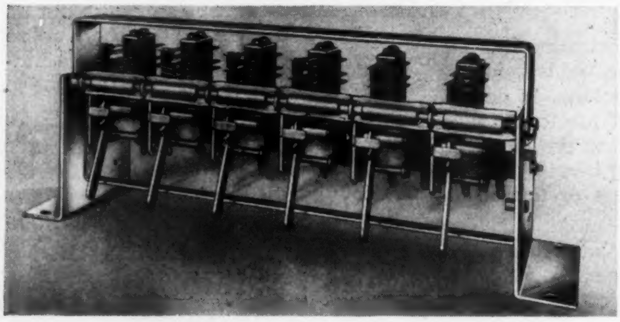


either extreme position when the solenoids are energized. When unenergized, the plunger is floating and its position is not controlled. In the latter type, the plunger returns to a neutral position when both solenoids are de-energized. Manufacturer: Trombetta Solenoid Co., 329 Milwaukee St., Milwaukee 2.

For further information circle MD 21 on Page 279

Relay Assembly for Indicator Circuits

Relay bank is designed for indicator circuits where numbers and signals, such as light or sound, are in sequence. When a coil is energized, the armature movement releases the reset arm. Arm then actuates switch combinations in the desired sequence, making or breaking depending upon the position of the arm. Armature cannot be released until reset arm is returned to the normal position. A lower bar extending across the bank resets the arm and armature on the relays. This bar may be actuated either



mechanically or electrically. Manufacturer: Guardian Electric Mfg. Co., Dept. T-11, 1601 Walnut St., Chicago 12.

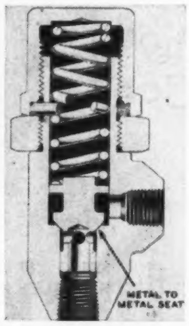
For further information circle MD 22 on Page 279

Plastic-Foam Insulating Material

Combining low thermal conductivity with light weight, plastic insulating material is particularly suitable for insulating trucks, railroad cars and airplanes as well as portable equipment. The snow-white plastic is made in shredded or block form. The shredded material has a density of from 0.8 to 1 lb per cut ft; block insulation weighs from 0.8 to 1.5 lb per cu ft. Blocks and slabs can be made in a variety of shapes and sizes and surfaced with paper, cloth or resin coatings. Thermal conductivity of the shredded form is 0.173 to 0.208 Btu per hr per sq ft per in. over a temperature range from 9 F to 100 F. Conductivity of the block material over the same temperature range is 0.20 to 0.23. Manufacturer: United States Rubber Co., Rockefeller Center, New York.

For further information circle MD 23 on Page 279

Hydraulic and Pneumatic Relief Valves



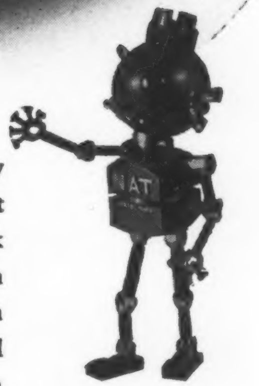
Relief valves for use with fluid pressures between zero and 450 psi are adjusted by positioning a threaded cap which varies spring pressure on a shut-off piston. Made with either metal-to-metal seat for hydraulic application or O-ring-to-metal seats, for pneumatic use, the units are made of brass or aluminum with stainless steel springs and pistons. Six standard sizes from ¼ to ¾-inch are made. Ratings available are 0-15, 10-50, 40-125, 115-250, and 235-450 psi. Manufacturer: Parker Appliance Co., 17325 Euclid Ave., Cleveland 12.

For further information circle MD 24 on Page 279

Piston-Type Hydraulic Pump

Four-piston hydraulic pump will operate in either direction of rotation and deliver fluid at pressures to 3000 psi. The pump mechanism, which weighs only 30 pounds, has four horizontally opposed pistons. Relief valves are incorporated in the pump and factory set at the desired pressure. At 1200 rpm driven speed, discharge pressure may be from 0 to 3000 psi with 5.4 to 3.0 gpm delivery. Di-

Tough Bolts for Rugged Work



These big, rugged bolts for heavy tractors, earth-moving equipment and heavy machinery are the "work horses" that handle unusually tough fastening jobs. Made from high carbon or alloy steel, with special heat-treatment, these bolts, when tightened, have extremely high resistance to stress, shear, fatigue and impact to prevent wear or breakage. They are made to perform hard tasks.

For special fastening jobs, "National" has designed and produced many special headed and threaded fasteners by the upset, cold headed process that have proved stronger and lowered costs. With its wide variety of manufacturing equipment used to make the most complete line of bolts, nuts, screws and other fasteners, "National" has the facilities to supply you with the right fasteners (large and small, standard or special) to make the products you manufacture fit better—stay tighter—or operate more smoothly.

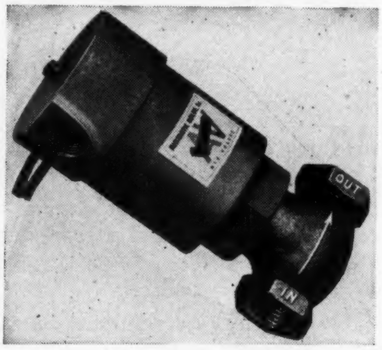
National
PRODUCTS

THE NATIONAL SCREW & MFG. COMPANY, CLEVELAND 4, OHIO

charge pressure is practically independent of driven speed. Manufacturer: Miller Hydraulic Engineering and Sales, 3615 Hart St., Detroit 14.

For further information circle MD 25 on Page 279

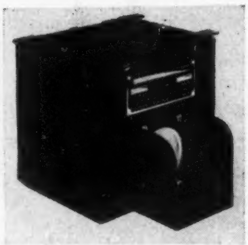
Direct-Operated Solenoid Valve



Designed to eliminate packing requirements, type DS-2 valve has a removable rubber seat which provides a leak-proof seal. The valve requires no pilot or other medium for operation. Its effective orifice area is equal to that of the pipe and it is suitable for operation on a-c or d-c and for use with oil, water, steam, air or process gases. Manufacturer: Airmatic Valve Inc., 1643 E. 40th St., Cleveland.

For further information circle MD 26 on Page 279

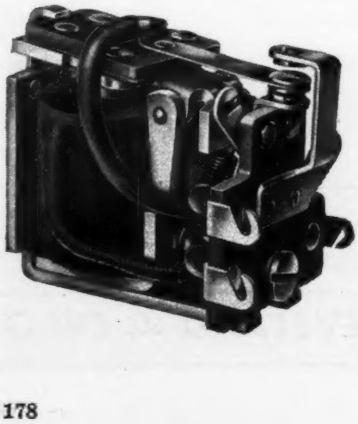
Photoelectric Switch



Sensitive only to light received from within a 5-degree arc, the Electronic Handyman photoelectric switch will measure light intensity as well as act as as a switch. A 2-inch diameter light-gathering lens together with a directional internal optical system makes possible various control applications without use of a sensitivity adjustment. The switch operates from 110-volts a-c and measures 4⅞ by 5⅛ by 4¼ inches. Manufacturer: John T. O'Connor & Co., 220 S. Valley Rd., West Orange, N. J.

For further information circle MD 27 on Page 279

Single-Pole Medium-Power Relay

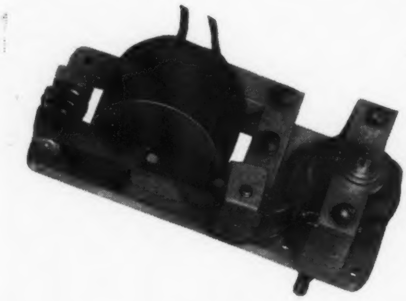


Medium - power type AS relay is made in less than one-inch width, facilitating its use in cramped installations. Dimensions are 1⅝ inches long, 1 13/16 inches high, and 15/16-inch wide. Weight is only 50 grams. Rated one watt, the relay is made for both a-c and d-c operation and in contact arrangements including normally closed, normally open or double throw. Its contact rating is 5 amperes at 24 volts dc or 110 volts ac. Type AS is insulated from the frame and a modification, type AR, is grounded to the frame but similar to AS in all other respects. Manufacturer: Allied Control Co. Inc., 2 East End Ave., New York 21.

For further information circle MD 28 on Page 279

Vibrator-Type Motor

Electric motor, known as the Vibratol, functions by means of high-efficiency a-c vibrator driving through a one-way clutch. Motor has the advantages of the



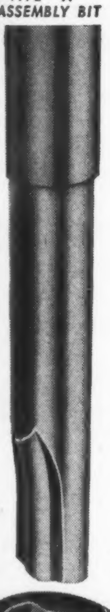
induction motor with the desirable performance characteristics of the series motor; thus has high starting torque, high overload capacity and good speed regulation. It creates no radio interference since there are no brushes or contacts to spark. Power requirements are 115 volts, 60-cycle current. Manufacturer: Piqua Machine and Mfg. Co., Piqua, Ohio.

For further information circle MD 29 on Page 279

Automatically Sealing Couplings

Combining automatic sealing with quick disconnecting, the series 1300 coupling is available with valve in either or both halves, of the coupling. When

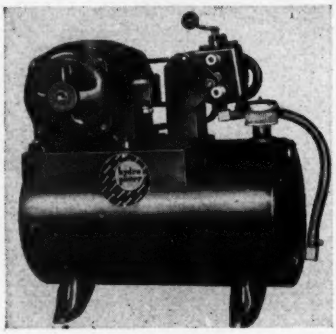
used together, the valves actuate one another so as to open when assembled and close when disassembled. Designed for trouble-free operation over a wide pressure and temperature range, the coupling is available in sizes from ¼ to 2 inches in Dural, bronze or steel. It is vibration proof and incorporates a full



swivelling action that prevents kinking of the hose. Manufacturer: Roylyn Inc., 718 W. Wilson Ave., Glendale 3, Calif.

For further information circle MD 30 on Page 279

Compact Hydraulic Pressure Unit



Compact power unit known as "Paul Bunyan Jr." is capable of supplying three gallons per minute of fluid at 1000 psi. The unit, which is suitable for the operation of all types of hydraulic apparatus, includes in an integral structure a 17-gallon storage tank, electric motor, gear pump and 4-way operating valve. Entire assembly occupies a space 15⅛-in. wide, 28-in. long and 29-in. high and weighs 290 lb. Normally supplied with a 1½-hp, 1800 rpm, 220 or 440-volt motor, the unit can also be used with a 2½-hp 1200 rpm, air-cooled gasoline engine. Manufacturer: Hydro-Power, Inc., Springfield, Ohio.

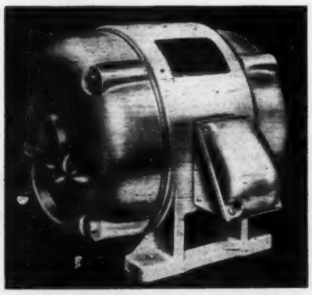
For further information circle MD 31 on Page 279

Epicyclic Drive

Simple and efficient mechanism for converting high-speed rotary motion into slow rotary reciprocation is built as an integral unit with sleeve or roller bearings. Design of the drive is said to permit considerable flexibility in both speed and stroke, making possible the use of built-in or direct-drive for the units where desirable. Where synchronous speeds are not required, rolling members may be substituted for gears, offering greater manufacturing economy. Manufacturer: American Brake Shoe Co., 230 Park Ave., New York 17.

For further information circle MD 32 on Page 279

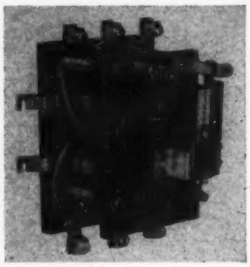
Splash-Proof General-Purpose Motors



New lines of electric motors called Permamotors include fractional-horsepower, integral-horsepower single-phase and integral-horsepower polyphase units. The fractional-horsepower motors are of the capacitor-start type having squirrel-cage rotors. They are made in frame sizes 56 and 66. Either bronze sleeve bearings or ball bearings can be provided. A quick-break switch and positive-acting governor has no sliding collar and is said to be the simplest form of governor developed for this purpose. Integral-horsepower motors are of the single-phase general purpose capacitor-start type. They are made in frames 203, 204, 224 and 225 in ratings from 1 to 5 hp. and are essentially squirrel-cage motors. Polyphase, squirrel-cage induction motors are available in frames 203 and 326. Motors are protected against splash and dirt and fittings are readily accessible. Permamotors are furnished in aluminum hammer-tone finish; various colors can be supplied for special-purpose applications. Manufacturer: A. O. Smith Corp., Milwaukee.

For further information circle MD 33 on Page 279

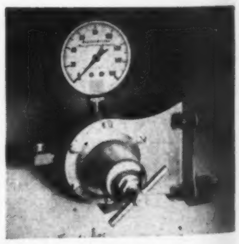
Close-Differential Current Relay



Noncreeping close-differential current relay is designed for use in process control where actuation is by change in current. It can be used, for example, to determine unbalances in circuits or change in current in a given circuit. Of a positive make and break type, it does not creep on opening or closing and adjustments are provided to permit field variation of factory settings. Maximum current capacity is 60 amperes and 1, 2 or 3 coils may be used, making the relay suitable for single or polyphase operation. Manufacturer: Automatic Switch Co., 387 Lakeside Ave., Orange, N. J.

For further information circle MD 34 on Page 279

Combination Regulating Valve and Gage



Pneumatic control unit consisting of reducing and regulating valve and pressure gage is available in four sizes to suit ¼, ⅜, ½ and ¾-inch pipe. Reducing regulating valve reduces primary pressure to a desired working pressure, automatically maintaining values required. Pressure gage records the working pressure. Each unit is provided with two rubber shock-absorbing vibration dampeners to protect valve and gage. Controllers are recommended for regulating pressures from 5 to 150 psi. Manufacturer: Dayton Rogers Mfg. Co., 2835 Twelfth Ave., Minneapolis 7.

For further information circle MD 35 on Page 279

Nylon-Reinforced V-Belt

Having twice the strength and four times the average life of conventional V-belts, Nylon-reinforced belt is particularly recommended for power transmis-


For NEW product design and sales advantages . . .
Compare YOUR motor needs with
The NEW COMPLETE FASCO LINE
of FRACTIONAL H.P. MOTORS
(Shaded Pole 1/500 to 1/8 H.P.)
1/50 and 1/30 H.P.
1/50 and 1/30 H.P.
1/500 to 1/100 H.P.
1/500 to 1/100 H.P.
1/50 to 1/25 H.P.
1/225 to 1/25 H.P.
1/20 to 1/8 H.P.
1/20 to 1/8 H.P.
1/50 to 1/25 H.P.
● Profitable competitive selling starts with successful competitive designing. You may find just the right competitive sales features you need in the new *complete* FASCO line of F.H.P. motors. And, the electrical and physical characteristics of these motors can be engineered by FASCO *experienced* know-how to adapt a *standard* motor to *your* product's *special* requirements. These FASCO quality-built motors are available in two and four pole models, at the H.P. ratings shown, rated for fan loads or power loads, for continuous or intermittent duty, with speeds from 1530 to 3075 Full Load R.P.M.
FASCO FRACTIONAL H.P. MOTORS AND BLOWERS
CONTENTS
WRITE FOR NEW CATALOG— Contains full information for the engineer and designer.
A PRODUCT OF FASCO
F. A. SMITH MANUFACTURING CO., INC., 550 DAVIS ST., ROCHESTER 2, N.Y.
FORMERLY Pilot MOTORS

sion on equipment subject to rough usage. The belt contains a series of Nylon cords covered with a special synthetic rubber compound capable of withstanding the deteriorating effects of heat and oil. Distributed under the name Super-Service V-Belt, the belt will be made in fractional and integral sizes. Manufacturer: United States Rubber Co., Rockefeller Center, New York.

For further information circle MD 36 on Page 279

Speed-Control Valve

Speed-control valve for use with hydraulic and pneumatic systems has a brass body and is suitable for use with oil, water or any hydraulic fluid. The compact unit has a wide range of adjustment achieved by turning the sleeve. It can be inserted at any point in a line and removed or replaced any time without disturbing the piping. Manufacturer: Galland-Henning Mfg. Co., Milwaukee 7.

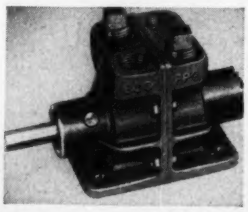
For further information circle MD 37 on Page 279

Hydraulic System

Consisting of hand pump, reservoir, two selector valves, and relief and check valves, Powerpak hydraulic control is capable of producing controlled pressures from zero to 1500 psi. The unit stands 4½ inches high, has a base measuring 3½ by 4 inches; ⅛-inch ports can be modified to suit individual needs. The reservoir capacity can be varied to meet individual requirements and a power driven pump can be utilized by connection to suction and pressure ports provided. Manufacturer: Electrol Inc., Kingston, N.Y.

For further information circle MD 38 on Page 279

Gearless Fluid Pumps

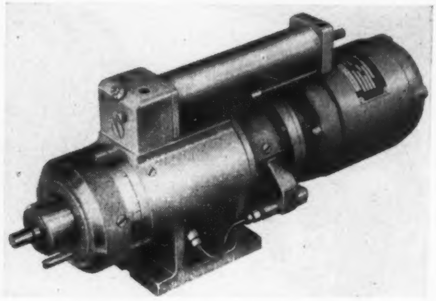


Based on the principle used in the Eco gearless marine pumps, a new line of pumps, is designed for general industrial use. They are smooth running and have double-impeller; bodies are stainless steel, Monel, or bronze to meet service requirements. Wearing parts can be easily replaced and parts in contact with fluid can be made of material to suit service requirements. Special impellers can be provided to suit the characteristics of the fluid handled. Units are made in ¼ and ½-inch sizes with capacities from 1 to 12 gpm. Delivery pressures up to 50 psi and operating speeds from 200 to 3500 rpm are available. Manufacturer: Eco Engineering Co., 12 New York Ave., Newark 1, N. J.

For further information circle MD 39 on Page 279

Hydraulic-Pneumatic Power Unit

Operating on 3-phase current and 50-psi air pressure, power unit will feed and rotate shafts rapidly and accurately. The unit incorporates a micrometer dial which allows adjustment within 0.001-inch. Shaft can thus be fed rapidly to chosen point, then slowly



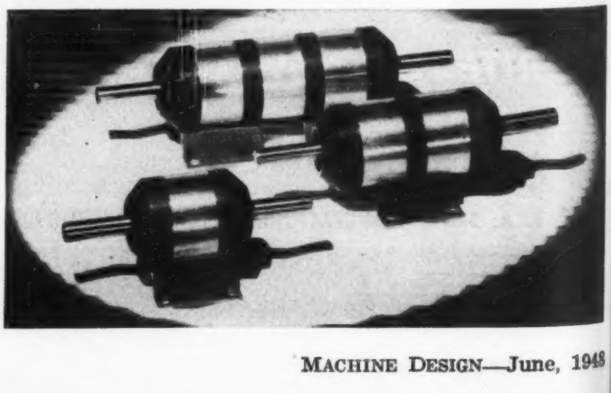
fed forward at predetermined speed to second point at which shaft will stop and then retreat. Maximum stroke is 1¼-inch and feed rate is 0 to 75-inches per minute. Motor rating is ¼-hp. Manufacturer: Cleveland Republic Tool Corp., 1265 Union Commerce Bldg., Cleveland.

For further information circle MD 40 on Page 279

Miniature High-Ratio Speed Changers

Multiple-section miniature speed changers are now made in units with ratios as high as 3375 : 1. Over 500 ratios ranging down to 9:10 are available in units measuring 1.050-inch in diameter and 4⅝-inches maximum length. Because of the use of hardened-steel permanently lubricated spur gears, speeds as high as 20,000 rpm at the high-speed shaft, and torques as high as 2 lb-in. at the low-speed shaft are possible. Input and output shafts are concentric and supported in ball bearings. Manufacturer: Metron Instrument Co., 432 Lincoln St., Denver 9.

For further information circle MD 41 on Page 279



THE GOOD RIGHT HAND OF INDUSTRY

Worthington CN Centrifugal Pump—its short oversize shaft means better service, longer life.

It's Versatile . . .

takes whatever drive is

handiest

Meet the "any-drive" pump—the new Worthington CN many-purpose Centrifugal that can be driven by the most convenient means available.

It's another general utility pump like the famous Monobloc—but without the motor. The liquid end is mounted on a frame, from which the shaft extends to be coupled to a motor, fitted with V-belt sheave, or what have you. In an emergency, you can quickly shift to another type of drive.

It's *rugged*—designed for overhung pulley-drive—rigid shaft maintains perfect alignment of pump parts. It's *flexible*—use interchangeably either packed stuffing box or mechanical seal.

More Pumps "Across the Board"

Worthington makes all types, all sizes of standard pumps. When you reach the point of specifying a pump for your equipment, remember that no company offers more pumps—no company offers more value in pumps—than Worthington. Send coupon for free bulletin showing why, in pumps, *there's more worth in Worthington.*

WORTHINGTON

MERCHANDISING DIVISION

The Good Right Hand of Industry

POWER TRANSMISSION: sheaves, V-belts, variable speed drives

PUMPS: centrifugal, power, rotary, steam

COMPRESSORS: horizontal, radial, vertical

Worthington Pump and Machinery Corp.
Merchandising Division, Dept. A89
Harrison, New Jersey

☐ Send latest bulletin on Worthington Centrifugal Pumps. Any other (type)........

Name..............................

Company..............................

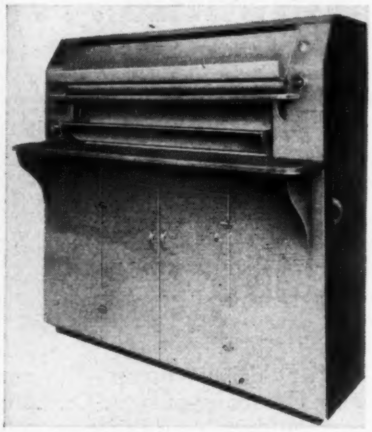
Address..............................

98-8

engineering dept equipment

In order to obtain additional information on this new equipment see Page 279

Tracing-Reproducing Machine



Equipped with Hanovia type printing tube and revolving cylinder, the Direc-Liner printing and developing machine will accommodate cut sheet and roll paper at high speeds. Of the ammonia - vapor type, the developer-printer is of packaged construction; printing or developing units may easily be removed and replaced from stock. Manufacturers: Reproduction Products Co., 12790 Westwood Ave., Detroit 23 and Economy Blue Print Products Co., 1714-20 N. Damen Ave., Chicago 47.

For further information circle MD 42 on Page 279

Radius Template for Circular Arcs

Drafting template facilitates rapid locating and drawing of circular arcs over a useful range of radii. The template, No. 76, is precision cut from 0.030-inch mathematical-quality plastic with all edges smooth and clean. Radii range up to 37/32-inches in 1/32-inch increments. Sizes and radius points on the 4¾ by 9¾-inch template are printed on the top side to prevent wearing off. Manufacturer: Rapidesign Inc., P. O. Box 592, Glendale, Calif.

For further information circle MD 43 on Page 279

Circular-Arc Template

Instrument known as the model B Arcmeter has a radius range from 20 inches to infinity. A true arc may be selected by means of a graduated scale without need of establishing a circle center. Adjustment is made by moving an indicator knob which is attached to a movable cam. The cam action, in turn,

affects the curvature of a steel spring which forms a perfect segment of a circle. High degree of accuracy and speed of operation make instrument a timesaver in either layout or checking of curves. Instrument measures 16 inches long by 3⅛-inches wide and produces a 15-inch arc. Manufacturer: The Arcmeter Co., 2016 6th St., Rockford, Ill.

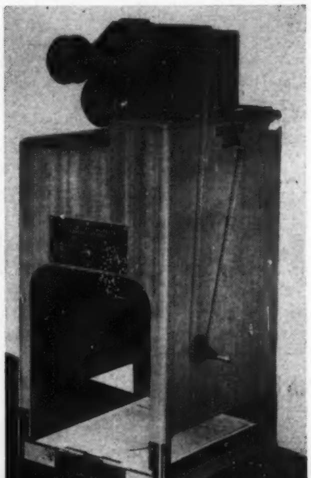
For further information circle MD 44 on Page 279

Photographic Reproduction Unit

Intended for use under normal room illumination to reproduce drawings in standard blueprint machines, Autopositive paper produces a high-contrast, positive copy direct from a positive original. The paper is used with standard equipment; it is exposed and then developed by normal photographic processing. Manufacturer: Industrial photographic division, Eastman Kodak Co., 343 State St., Rochester 4, N. Y.

For further information circle MD 45 on Page 279

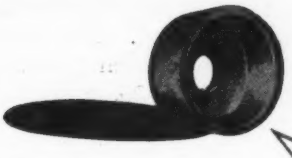
Microfilm Camera-Reader Combination



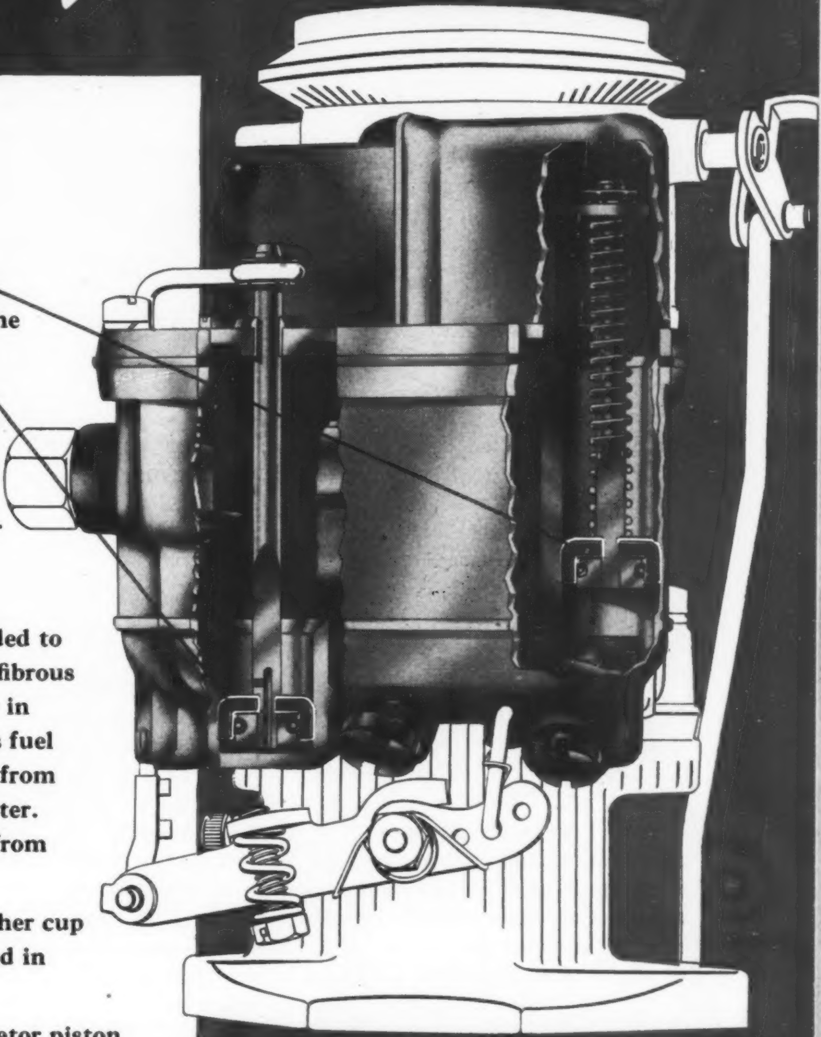
Combination Microfilm camera and reader is portable, weighing only 45 lb. It will photograph any material measuring up to 11 by 14 inches, reproducing it on 35 mm film from which it will make exact - size prints. Lenses, shutter, aperture and lights of the unit are preset. Automatic indexing is also provided. When used as a microfilm reader, the apparatus projects a full - size image upon the surface used for original photography, insuring close dimensional fidelity. Used as a microfilm camera the machine has only to be loaded and the camera

IN ENGINEERING, AS IN DRIVING

it's little things that count



Like that little squirt of gasoline, when you want quick starting and fast pick-up. And the little piston pump packing which helps you get it. In Stromberg carburetors (made by Bendix Aviation Corp.), special care is taken to assure complete dependability of *every* component part. In model BXVD-3, for instance, two leather cup packings are used—one on the dash pot piston and the other on the pump piston.



These cup packings must be accurately molded to size; they must *stay* wrinkle-free; and their fibrous texture must have that tightness found only in prime calfskin. These cups must not by-pass fuel or become logged; they must neither shrink from heat nor freeze to their cylinder walls in winter. Their leather tannage must not deteriorate from contact with oils or gasoline.

Non-deteriorating *chrome* tanned Sirvis leather cup packings, made by Chicago Rawhide, are used in thousands of Stromberg carburetors.

Chicago Rawhide engineered the first carburetor piston pump packing to deliver satisfactory performance. Today, they are used in many leading makes. Because of constant research and product development, precise laboratory control, highest standards of leather quality, and exceptional care in every phase of production, Chicago Rawhide's Sirvis leather piston pump packings continue to be the most dependable.

CHICAGO RAWHIDE MANUFACTURING CO.
1304 Elston Avenue   Chicago 22, Illinois

for assured performance

in your leather applications—whether in connection with oils, grease, water, or air, under high, low or static pressures—specify SIRVIS. Your inquiries will be promptly answered.

New York • Philadelphia • Detroit • San Francisco
Cleveland • Boston • Pittsburgh • Los Angeles
Minneapolis • Syracuse • Peoria

OUR 70th YEAR OF INDUSTRIAL SERVICE

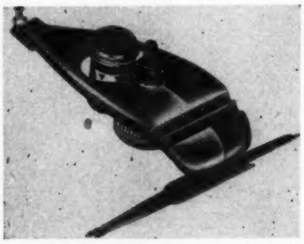
SIRVIS
MECHANICAL LEATHERS

OTHER C/R PRODUCTS
PERFECT Oil Seals
SIRVENE Synthetic Rubber

snapped for each document placed in the reproducing space. Processing and indexing of the film is provided by the manufacturer. Manufacturer: Microfilm by Microstat, 132 W. 43d St., New York 18.

For further information circle MD 46 on Page 279

Ink-Bottle Holder



Holder for ink bottles and pens may be used regardless of angle of the board, providing a convenient receptacle which will keep them from falling off of the work surface. The holder is made of heavy-gage aluminum finished in gold, brown, red or natural color. It is attached to the board by means of a thumb tack. Manufacturer: The Wayne Products Mfg. Co., 103 South Wells St., Chicago 6.

For further information circle MD 47 on Page 279

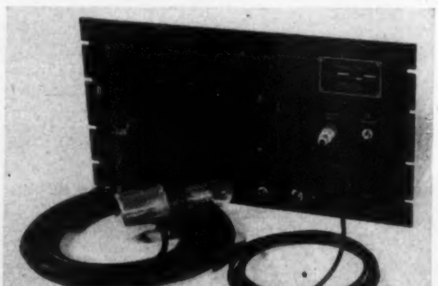
Shading Medium

Tissue-thin, adhesive-backed transparent sheet may be chemically shaded over any desired area, making it particularly suitable for rapid shading of drawings. In use, the "V-Film" is applied over the area to be shaded and a developing chemical applied with a brush. Previously invisible pattern then appears as sharp dark tone. The film can be stripped off the drawing after use without damage and a new pattern substituted. Several films having different patterns can be applied one over the other. Manufacturer: Craftint Mfg. Co., 1615 Collamer Ave., Cleveland 10.

For further information circle MD 48 on Page 279

High-Speed Photoflash Unit

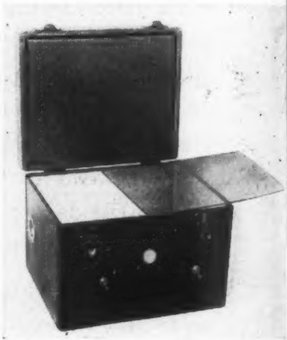
Providing light flashes of extremely short duration, the model 400 Photometering unit can be used for photographing fast-moving machinery or instrument



dials. Flashes are triggered by an external electrical pulse so that they can be synchronized with other apparatus or with the position of a moving object. Objects at a distance of up to three feet can be photographed at 50 microseconds with moderate lens openings using up to three lamps. Triggering pulses can be at regular or irregular intervals at a speed up to about 20 per second, overall time delay from the start of the triggering pulse to the flash is of the order of 40 microseconds. Unit measures 10½ inches high, 8 inches deep and is designed for 19-inch telephone-rack mounting. The weight is 25 pounds. Manufacturer: Photographic Products Inc., 9032 W. Pico Blvd., Los Angeles 35.

For further information circle MD 49 on Page 279

Photo-Copying Machine



Designed to meet the need for efficient, inexpensive, reproduction equipment, the Bantam model Tru-Copy - Phote machine has a reproduction surface measuring 8½ by 11 inches. Portable electric unit, the machine operates on 115 volt, ac or dc, in ordinary office light without need of dark rooms, focusing or heating equipment. Uses include reproduction of drawings, photographs, charts, letters, etc. Manufacturer: General Photo Products Co., General Photo Building, 15 Summit Ave., Chatham, N. J.

For further information circle MD 50 on Page 279

Parallel-Ruling Straightedge

Featuring extra-heavy guard over cable, the E-Z Grip straightedge is 5/16-inch thick, facilitating moving of the straightedge up or down the drafting board or lifting it off the board. Bevel angle has been set in such a manner that a comfortable grip is obtained and there are no sharp corners or contours on either side. Both blade and cap of the straightedge are black laminated plastic; clear edges are set into the edge of the blade. Guiding units are four ball-bearing mounted pulleys which control the action of a Monel cable. Manufacturer: Engineering Mfg. Co., Sheboygan, Wis.

For further information circle MD 51 on Page 279

Assets to a Bookcase

Waterbury's Handbook of Engineering

By L. A. Waterbury, late professor of civil and architectural engineering, University of Arizona; revised by H. W. Reddick, W. M. Lansford, C. O. Mackey, H. H. Higbie and H. S. Bull; published by John Wiley & Sons Inc., New York; 386 pages, 3 by 5⅝ inches, clothbound; available through MACHINE DESIGN, $2.50 *postpaid.*

Fourth edition of a book originally published in 1908, this volume has been brought up to date by the addition of two sections and the revision of the entire contents. In its modern thumb-tabbed form it contains five divisions, each devoted to a different aspect of enginering and each prepared by an expert in the field. These are: Mathematics, mechanics, heat engineering, electrical engineering and electronics. In each, basic formulas are offered, data is tabulated and examples are given. Such valuable information as tables of integrals, equations for moments and stress-computation formulas is presented at some length. A useful appendix contains tables of logarithms of numbers, sines, cosines, tangents and cotangents, as well as natural sines, cosines, tangents and cotangents, and conversion tables for fundamental dimensions.

□ □ □

Nomography

By Alexander S. Levens, associate professor of mechanical engineering, University of California; published by John Wiley & Sons Inc., New York; 176 pages, 6 by 9¼ inches, clothbound; available through MACHINE DESIGN, $3.00 *postpaid.*

Discussion of the preparation of nomograms, or alignment charts, in this book is thorough and careful. The author has developed his material as an outgrowth of courses on nomography at the University of Minnesota and the University of California and has used the experience thus gained to guide him in the selection and treatment of his subject matter. Emphasis has been placed upon the geometric method for the development of theory on the design of charts involving equations of three or more variables. Simple equations are solved by alignment charts consisting of straight-line scales and more involved equations make use of grids, curved scales and combinations of Cartesian co-ordinate charts with alignment charts. First three chapters of the book discuss the theory of charts and functional scales, while the last two chapters go into short cuts and the use of determinants for chart making; the balance of the volume is devoted to systematic coverage of the seven types of equations most frequently encountered, and their solution by geometric methods. A thirty-page appendix gives numerous examples of alignment charts useful in fields of engineering.

□ □ □

Modern Metallurgy of Alloys

By R. H. Harrington, research laboratory, General Electric Co.; published by John Wiley & Sons Inc., New York; 209 pages, 5¼ by 8¼ inches, clothbound; available through MACHINE DESIGN, $3.50 *postpaid.*

Discussing modern metallurgical theory, stressing the "whys" of alloying, this book should be of particular value to engineers. Instead of plunging into complicated phase theory and space structures of metals, the author has developed his study logically and gradually, first building a groundwork of terminology and on this constructing his more advanced discussion. Subjects covered include factors influencing alloying, double aging with intermediate plastic strain, crystalline structures, and the physics and chemistry of alloying. Well illustrated and replete with tables, the volume should serve as a ready and useful reference book for designers dealing with high-strength materials.

Newly revised American standard covers involute splines in a greatly expanded range of sizes and tooth numbers. Among subjects discussed are: Size range and pitch, fits, pressure angles, torque capacities and spline selections for bearings. Paperbound, the 60-page booklet measuring 8 by 10½ inches is available at $1.00 from the American Standards Association, 70 E. 45th St., New York 17.

"Symposium on Testing Bearings," published by the American Society for Testing Materials, is a 65-page volume containing five papers presented before the annual meeting of the Society. Covered are life testing of sleeve bearings, fatigue testing machines for ball and roller bearings, testing of bearings under controlled load, fatigue testing of roller bearings and ball-bearing fatigue phenomena. The paperbound 6 by 9 inch book is available from the American Society for Testing Materials, 1916 Race St., Philadelphia 3 for $1.50

How Manufacturing Costs Are Cut With Arc Welding

By Cecil Peck, President
Cecil Peck Company
Cleveland, Ohio

EXPERIENCE shows that the simplest way to convert a machine design to welded construction for lower costs is to *change one part at a time*. This gradual transition provides the engineers with practical know-how before they tackle the entire problem and allows the shop to switch over without disrupting production.

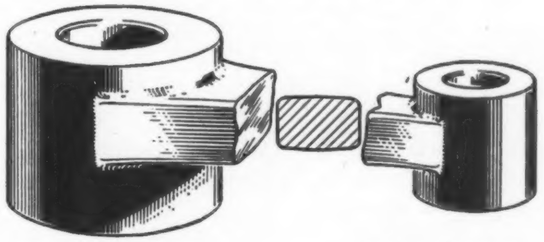
Most manufacturers start with simple parts such as levers, brackets and wheels.

Take, for example, the lever shown here. Fig. 1 shows an original design providing details of size and form. The first design step, shown in Fig. 2, simply meets the requirements of the job. The lever is built by fillet welding a flat bar to hollow tubes acting as hubs. While such a design is desirable from a standpoint of weight and cost reduction, if a side thrust or another known force exists, additional strength can be obtained by increasing the thickness of the bar (with an increase in material cost) or the section detail can be changed.

Here are other approaches: An "I" section can be built-up easily from three steel straps as shown in Fig. 3. Preferable, however, is a box detail made from two formed "U" sections illustrated in Fig. 4. A box section allows a thinner wall and cuts welding time in half. This latter design is extremely strong, light, has stiffness and torsional rigidity.

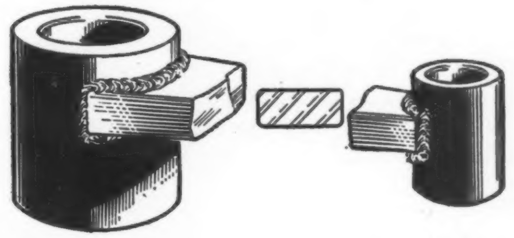
In establishing any final design, several additional factors should be considered: the number of duplicate parts to be made at one time and the type of forming equipment available. Each factor must be properly analyzed to determine which of the contemplated designs can be built in the shop at the *lowest cost per piece*.

Fig. 1. Original Design



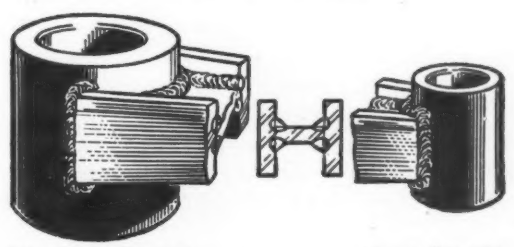
Weight 62.5 lbs. **Cost $5.98**

Fig. 2. First Redesign



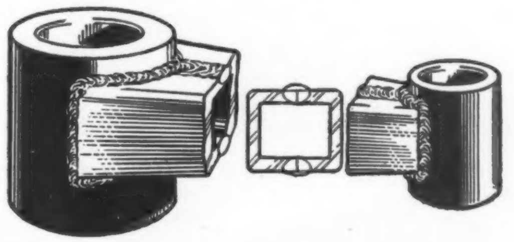
Weight 29.3 lbs. **Cost $3.57**

Fig. 3. "I" Section



Weight 23.5 lbs. **Cost $3.78**

Fig. 4. Box Section

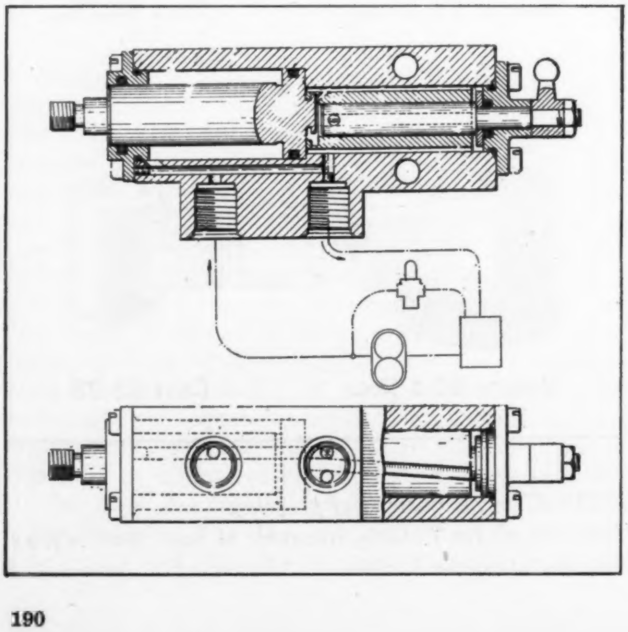


Weight 20.5 lbs. **Cost $3.23**

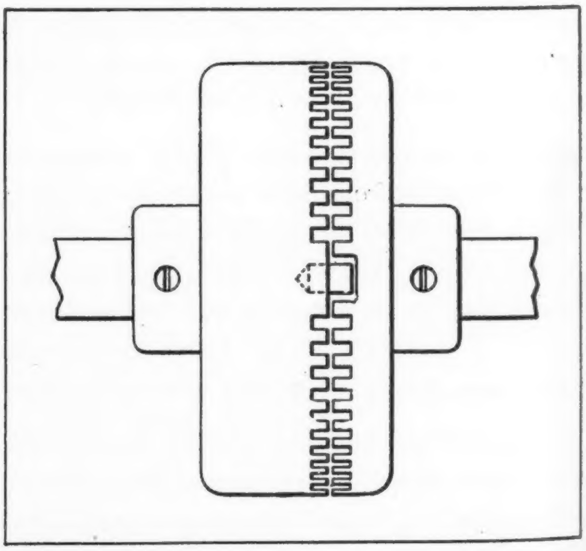
Noteworthy Patents

ROTARY WIRE BRUSH-LIKE MEMBERS, having their faces in frictional engagement, provide the driving means for constant or variable-speed power transmissions. Covered by patent 2,424,873 assigned to the Osborn Mfg. Co., by H. R. Abbrecht, these brush-like members can be varied to suit the transmission design and the power to be transmitted. Transmission capacity is governed by the size, stiffness and other characteristics of the stranded brush material employed. In driving, these members afford a degree of flexibility so as to obviate undesired starting and stopping load shocks but drive is positive to the extent that slippage only occurs where load exceeds the rated capacity.

PRECISE linear actuating movements of short or long stroke with accurately controlled power amplification are readily attained by means of a unique combination hydraulic cylinder and valve unit covered in patent 2,434,668. Utilizing pressure differential to obtain automatic operation of the piston in both directions, the unit is constructed with a rotary valve directly attached to the piston. An axially disposed metering groove along the valve body is brought into register with the actuating pressure port by a small rotary movement of the valve handle. By employing modifications in the position and shape of the valve groove, a variety of controlled movements can be obtained for operation of automatic gear shifting, gun fire computers, etc. Force required to actuate the valve handle is small and power output of the unit is smooth and uniform. Unit patented by Edward M. May.



MAGNETIC ATTRACTION is utilized to transmit torque from one member to the other of a coupling assigned to General Electric Co. by L. W. Wightman under patent 2,435,112. Torque transmitted is limited by the maximum magnetic forces which can be exerted by the mutually attracted permanent-magnet teeth of the coupling members. One variation of the design, however, overcomes this shortcoming by means of a direct driving dog which extends into a



mating socket and comes into play under high-torque conditions. Design of the dog drive is such as to allow circumferential displacement of the teeth of the two members to the point of maximum magnetic force between the teeth. At this point direct drive takes place in addition and as soon as torque requirements return to normal, full magnetic drive is restored.

Do You Have a Problem in TURNING WHEELS?

Maybe you have a job that you never dreamed could be done with a V-belt. Perhaps we at U. S. Rubber can help—we are constantly solving such problems . . . sometimes by designing V-belts which help safeguard human life—on submarines, for example.

U. S. Rubber engineers have designed a V-belt as small as $4\frac{3}{4}$ inches in circumference, and as large as 55 feet. They have solved such a wide range of V-belt problems that today, if you want "a special" in a hurry, chances are it can be obtained without making a new mold.

For more information, write Mechanical Goods Division, United States Rubber Company, 1230 Avenue of the Americas, New York 20, N. Y.

U. S. RAINBOW

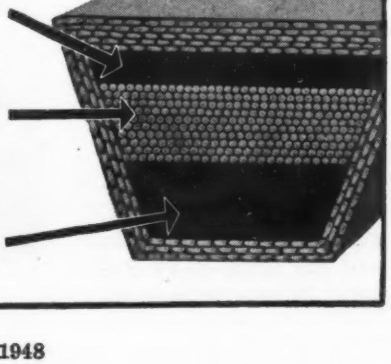
V-BELTS

WITH THE EQUA-TENSIL CORD SECTION

Top Rubber Cushion in closely-engineered balance with the lower section . . . to keep cool under constant stretch and turn.

Equa-Tensil Cord Section—all cords scientifically placed, each pulling its share of the load.

A sturdy level cushion for the Equa-Tensil Cord Section. Provides structural firmness for V-grooves and over the flat pulley of V-to-flat drives.



MADE BY

U.S. RUBBER

SERVING THROUGH SCIENCE

UNITED STATES RUBBER COMPANY

MEN... of machines

WILLIAM R. HOUGH, chief engineer of the Reliance Electric & Engineering Co. since July, 1945, has been elected the company's engineering vice president. Associated with Reliance for nineteen years, Mr. Hough joined the organization as a cadet engineer in 1929 following graduation from the University of Michigan. Advancing through the positions of junior design engineer, head of drafting and mechanical design activities, and experimental engineer, Mr. Hough in 1941 was selected to take charge of the company's a-c motor design engineering program. During the three years he served in that capacity he designed variable voltage-frequency a-c runout table drives with patented floating motor mounting as well as working out design details covering many special-purpose motors which found wide application on critical Navy equipment during the war period. As head of product development engineering during 1944 and 1945, Mr. Hough was responsible for new design engineering work on the company's a-c polyphase induction motors, d-c motors and adjustable-speed drives including controls. Significant product developments accomplished during his service as chief engineer include an interlock regulator for sectional drives; electronic and magnetic assemblies such as photoelectric guide control for motor-driven reels; rotating-type regulator for voltage, speed, or current control; and special a-c and d-c motors for coal mining machinery. Mr. Hough also has been a contributor to the technical press.

William R. Hough

Dr. T. K. Glennan

DR. T. KEITH GLENNAN, recently installed as president of Case Institute of Technology, is first business executive to head the institute. Dr. Glennan was graduated "cum laude" in electrical engineering from Sheffield Scientific School of Yale University in 1927. His career has been devoted principally to sound equipment work, first with the motion picture industry and from 1942 to 1945 as director of the U. S. Navy Underwater Sound Laboratory. In the latter position he directed a large corps of engineers, scientists and naval personnel on ships in the laboratory's service, guiding the development of various submarine detection and location devices. One of these, the expendable radio sono-buoy, is described as one of the outstanding developments of the war and played a decisive role in the battle of the Atlantic. For his service with the Underwater Sound Laboratory, Dr. Glennan was awarded the medal for merit, highest civilian award which the government can bestow. Since January, 1946 and prior to his appointment as president of Case in June, 1947, Dr. Glennan was associated with the Ansco Div., General Aniline & Film Co.

R. C. HEINMILLER has accepted the position of chief engineer for LeMaire Tool & Mfg. Co., Dearborn, Mich., builders of special machine tools. For more than twenty-five years Mr. Heinmiller was associated

R. C. Heinmiller

★ SEAMLESS STAINLESS STEEL
★ GLOWELD WELDED STAINLESS STEEL
★ SPECIAL ANALYSES STEEL
★ SANITARY
★ CORROSION RESISTANT
★ POLISHED INSIDE AND OUT
★ SEAMLESS MECHANICAL
★ MACHINEABILITY
★ STRENGTH
★ CLOSE TOLERANCE
★ ANNEALED AIRCRAFT
★ GLOBEIRON HIGH PURITY INGOT IRON
★ HIGH MAGNETIC PERMEABILITY
★ DUCTILITY
★ PRESSURE
★ HIGH TEMPERATURE SERVICE
★ AUTOMOTIVE
★ CARBON
★ ALLOY
★ ROUND
★ SPECIAL SHAPES AND FORMS

SELECT FOR YOUR EXACT REQUIREMENTS

by class or type of steel tubes from GLOBE

Yes, you can select your exact requirements — by class or type steel tubing in almost any size — from Globe Steel Tubes Company.

What's more, you can be absolutely sure of getting a product in exact conformity with your requirements. That's because Globe Steel Tubes Co., meeting your needs, applies all the manufacturing and engineering "know-how", gained by exclusive specialization for nearly forty years in the production of steel tubing.

Equally important, you get the benefit of the most advanced volume production methods and rigid controls. To maintain the exact uniformity and high quality, constant chemical and physical checks and tests are conducted by Globe Steel Tubes Co.'s own completely equipped laboratories.

If you have a problem involving steel tubes—*stainless, mechanical* or *pressure* —consult Globe Steel Tubes Co. Globe engineers will give you the benefit of their specialized knowledge in a wide range of services and applications . . . to help make your product better . . . to increase your production . . . to lower your costs. GLOBE STEEL TUBES CO., Milwaukee 4, Wisconsin.

GLOBE

STEEL TUBES

with the Foote-Burt Co. in various engineering capacities, including plant engineering and the development and supervision of the electrification of Foote-Burt drilling machines. He was also associated for six years with Warner & Swasey Co. Mr. Heinmiller is a mechanical engineering graduate of Case Institute of Technology and a registered professional engineer in Ohio.

♦

HOWARD M. HUBBARD has been named president of the Hydraulic Press Mfg. Co. A graduate of Northeastern University and the Harvard Graduate School of Business Administration, Mr. Hubbard has received degrees in both engineering and business administration. He has served as president of the Elliott Co. and Greenfield Tap & Die Corp. and, for the past three years, has been engaged as a consulting and development engineer.

♦

HARRY BERNARD replaces W. M. WALWORTH who has resigned as chief engineer of Mack Trucks Inc. Mr. Bernard, for the past three years director of service and service engineering, now assumes overall responsibility for the engineering of the company's entire line of trucks, buses and fire apparatus.

♦

JOHN K. HODNETTE, recently elected a vice president of Westinghouse Electric Corp., retains his post as manager of the Transformer division to which he was named in 1946. A mechanical engineering graduate of Alabama Polytechnic Institute, Mr. Hodnette joined Westinghouse in 1925 and was first assigned to transformer engineering and design at the Sharon, Pa., plant. One of his outstanding achievements in this field was the development of a power distribution transformer completely self-protected against lightning and electrical overloads.

♦

CARL W. LANGE, who, before his retirement, was engineer in charge of the d-c armored motor division of the General Electric Co., has been awarded the company's highest honor, the Charles A. Coffin foundation award, for having conceived and redesigned the standardized line of heavy-duty mill type motors. CLAUDE B. HUSTON, engineer in the industrial engineering division, received a similar award for designing an unusual and improved type of control for reversing blooming and slabbing mills in steel plants.

♦

KERMIT T. KUCK, chief engineer, has been elected engineering vice president of the Monarch Machine Tool Co. Mr. Kuck, an engineering graduate of Ohio State, joined the company in 1934, spending the following five years in practical training and in the company's engineering department. After several years association with the sales department, Mr. Kuck was appointed chief engineer in 1943.

♦

STANLEY R. HOWARD recently was elected vice president in charge of engineering of the Pneumatic Scale Corp., Ltd., North Quincy, Mass., manufacturer of packaging machinery. Mr. Howard joined the company shortly after graduation from Harvard and was first employed as a draftsman. Following service with the Army during the first World War, Mr. Howard was appointed chief engineer of the company in 1919 and has been prominent in all the company's research, invention and development work.

♦

L. LEE SCHAUER, chief engineer of the Cincinnati Bickford Tool Co., has also been elected a vice president.

♦

ROBERT E. BUSEY, who has been serving as acting chief engineer of Willys-Overland Motors, has been promoted to chief engineer. He will be responsible for body and chassis engineering, the engine division and research and development.

♦

E. C. LANNO, formerly of the Detroit Diesel Engine Div., General Motors Corp., has been named development engineer of the Rockford Clutch Div., Borg-Warner Corp. Mr. Lanno, a graduate engineer, has had several years practical experience in the development of clutches, power takeoff and gear reduction units, and in the industrial field. He replaces L. F. MOHNS, resigned.

♦

LEOPOLD M. KAY has been elected vice president in charge of engineering, Air King Products Co. Inc., Brooklyn, N. Y. Prior to joining the organization two years ago as chief engineer, Mr. Kay had been associated with Raytheon Mfg. Co. as research engineer.

♦

DR. K. C. BLACK has joined the staff of Air Associates Inc., Teterboro, N. J., as chief radio engineer.

♦

RODNEY B. CAMPBELL has joined the Lynn Co., Burbank, Calif., as chief hydraulic engineer. Mr. Campbell designed a number of the early hydraulic applications in aircraft. He served as chief engineer of the Aeron Corp. during the war and has been engaged in hydraulic research since that time.

♦

DWAIN E. FRITZ has joined the development engineering staff of Jack & Heintz Precision Industries Inc., Cleveland. For the past two years Mr. Fritz was manager of the aircraft motor and generator section, aviation engineering department of the Westinghouse Electric Corp. at Lima, O.

♦

WILLIAM B. WALLIS, president of the Pittsburgh Lectromelt Furnace Corp., Pittsburgh, was elected president of the American Foundrymen's Association during its recent annual convention.

♦

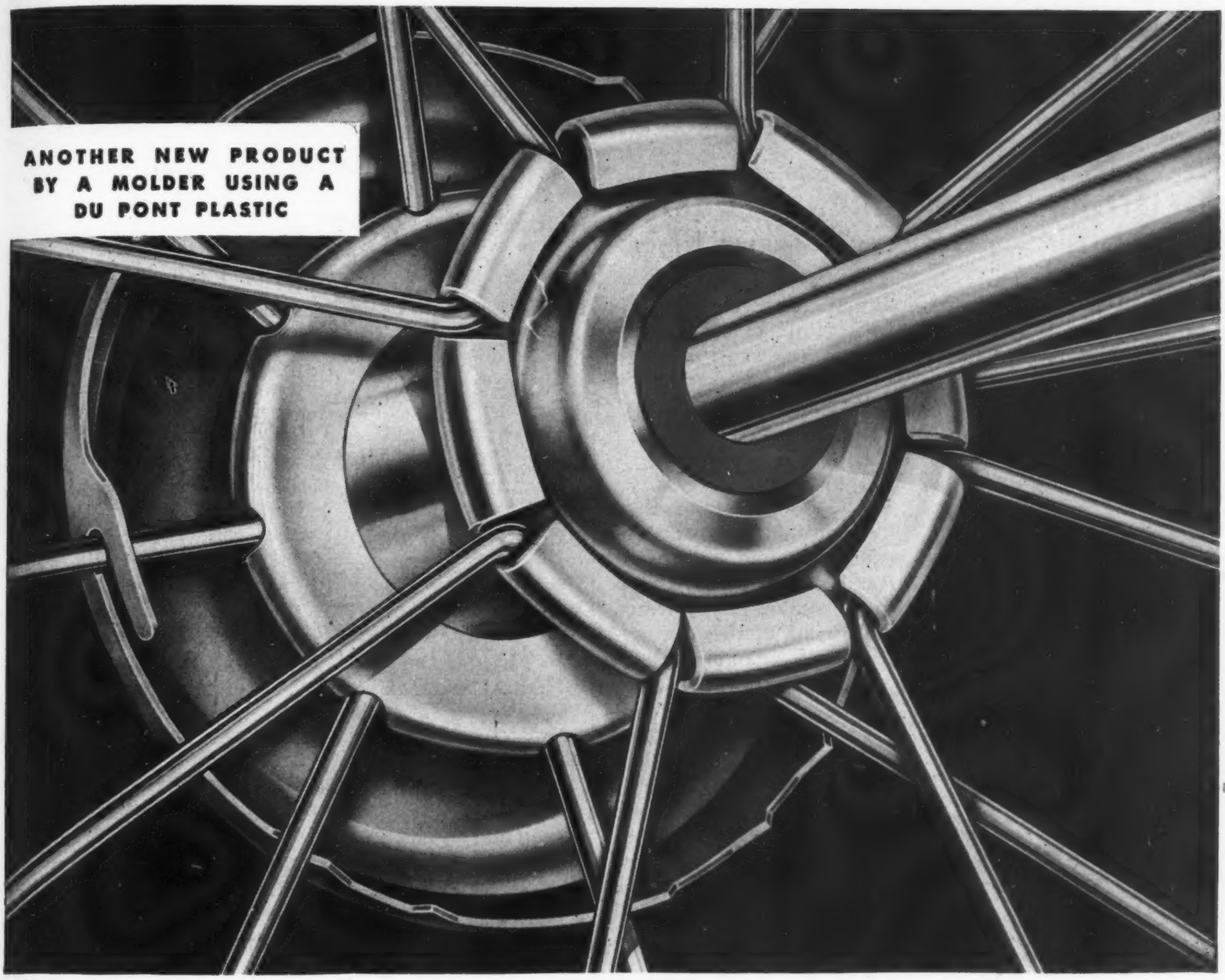
W. H. ROWAND, associated with Babcock & Wilcox Co., New York, for 19 years, has been appointed chief engineer. Mr. Rowand will assume most of the engineering activities previousy handled by ALFRED IDDLES who is now president of the company.

♦

ARTHUR R. CONSTANTINE recently was appointed director of engineering for the Indian Motocycle Co., Springfield, Mass.

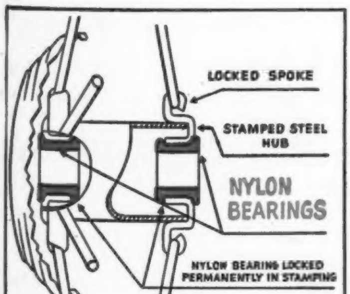
♦

I. F. KINNARD has been appointed manager of engineering of the meter and instrument division of General Electric Co.



NYLON PLASTIC CUTS RUB IN THE HUB

Bearing of Du Pont nylon needs no lubrication . . . rolls quietly



Need bearings in your business? Why not investigate Du Pont nylon plastic? Nylon is silent . . . no squeaking, and creaking. Nylon bearings won't chip, flake or powder . . . need no lubrication when loads are light and speeds are low. In the textile industry, for example, this means no oil spots on fabrics. Nylon has proved satisfactory for bearings with walls as thin as 1/16″ . . . for bearings as large as 1½″ O. D. It may mean new profits for *you*.

Nylon's making news again—this time on the wheels of a baby carriage. In tests made on these wheels, bearings molded of tough, durable Du Pont nylon *actually lasted longer* than the metal axles. And they need no lubrication . . . withstand shocks and blows.

In other applications where loads are heavier, speeds are high, and lubricants are required, either oil or water can be used. Du Pont nylon plastic is not affected by oils and greases, chemicals and solvents . . . withstands service temperatures as high as 325°F. Nylon bearings show little or no deterioration with age. And injection molding permits rapid, large-scale production.

Is there a place for nylon in your business? You may profit with this and other Du Pont plastics . . . in developing a new product or improving an old one. Write now for literature. It will pay you to have it in your files. E. I. du Pont de Nemours & Co. (Inc.), Plastics Department, Room 396, Arlington, N. J.

Baby carriages manufactured by Collier-Keyworth Co., Gardner, Mass.; nylon bearings molded by Nylon Bearings, Inc., Whitman, Mass.

Listen to Du Pont "CAVALCADE OF AMERICA" *—Every Monday Night, NBC Network*

DU PONT
REG. U. S. PAT. OFF.
Plastics
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

Offset Pivot Reduces Sector Gear Noise

(*Concluded from Page 132*)

$$\frac{dC}{dB} = \frac{1}{2\tan\phi}$$

or $dB = B \tan\phi\; dC$. Also, since $B = B_c \cos\phi$, $dB = \cos\phi\; dB_c$, from which

$$dB_c = \frac{2\tan\phi\; dC}{\cos\phi}$$

When the increments become B_c and C, respectively

$$B_c = \frac{2\,C\tan\phi}{\cos\phi} \qquad (5)$$

For $\phi = 20$ degrees, $B_c = 0.775\ C$. If tooth errors are present, the backlash may be less than Equation 6 indicates.

CENTER DISTANCE CORRECTION: If the sector pivot does not permit mesh adjustment, the center distance will need correction. It is evident from the illustrations that the center distance between sector pivot and pinion is not simply $R + r$, or $R - r$, but is a function of the angular amplitude angle, θ.

For an external gear, *Fig.* 1, the center distance is equal to

$$D_E = \sqrt{(R+r)^2 - e^2\sin^2\theta} - e\cos\theta \qquad (6)$$

or, if $(R+r)^2$ is large compared to $e^2 \sin^2\theta$, which would be usual,

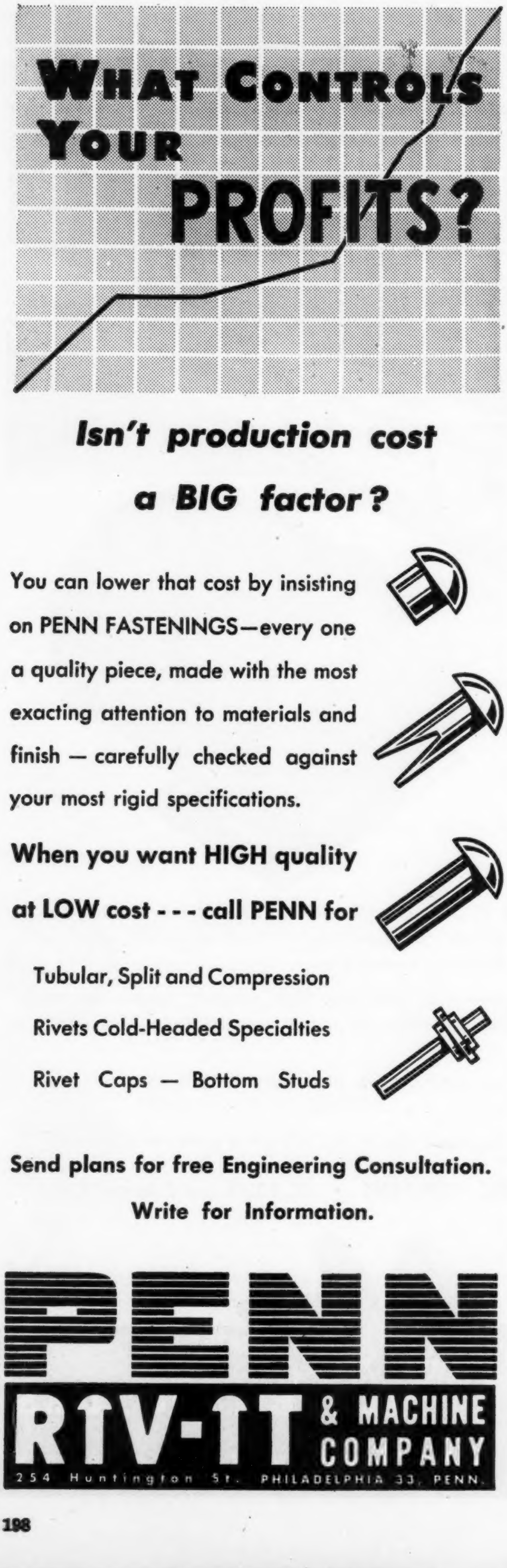
$$\begin{aligned} D_E &= R + r - e\cos\theta \\ &= (R+r) - (e - C) \qquad (7) \end{aligned}$$

Since $e > C$ except when $\theta = 90°$, it can be seen that the ideal center distance needs to be decreased by $(e - C)$.

For an internal sector gear, *Fig.* 3, similar analysis leads to the relationships

$$\begin{aligned} D_I &= R - r + e\cos\theta \\ &= (R-r) + (e - C) \qquad (7a) \end{aligned}$$

PUSHBUTTON CONTROL of dual-fuel internal combustion engines has further simplified the changeover from diesel oil to gas or vice versa. On the new Superior engine, a button marked OIL and one marked GAS are the only controls necessary for effecting changeover. Should the gas supply be insufficient to meet load demand, the governor automatically furnishes sufficient oil to make up the deficiency.



BUSINESS AND SALES BRIEFS

NAME of the American Rolling Mill Co. was officially changed to Armco Steel Corp. at a recent meeting of the stockholders. At the same time W. C. Breed, E. A. Deeds, C. S. Payson and Calvin Verity were re-elected directors of the corporation.

According to a recent announcement the Midwest Tool & Mfg. Co. of Detroit has moved its plant, manufacturing facilities and executive offices to Upper Sandusky, Ohio. Offices are being retained at 2360 W. Jefferson Ave. in Detroit and 549 W. Washington Blvd. in Chicago.

Eugene W. Fuller has been elected vice president of Shakeproof Inc., a division of Illinois Tool Works where he will direct manufacturing and sales of the division. Concurrently, Carl F. Jensen has been appointed district sales manager of the midwest area for the company. Mr. Jensen will have his office in Chicago and will direct sales activities in Illinois, Indiana, Wisconsin, Minnesota, Iowa, Missouri and Western Ohio.

New line of over-running clutches will be marketed by Morse-Formsprag Sales department, a division of Morse Chain Co. Manufacture of the clutch will be by The Formsprag Co. Manager of the newly formed department will be Henry R. Greenley who will continue his duties as manager of the present Morse Coupling sales department.

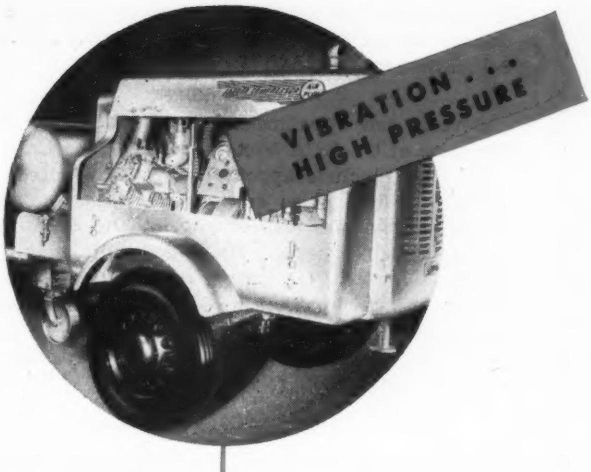
Formerly affiliated with the Holtzer-Cabot Div. of the First Industrial Corp., L. H. Littlefield has been appointed general sales manager for the Wolverine Tube Div. of Calumet & Hecla Consolidated Copper Co. Inc. Mr. Littlefield's headquarters will be in the general offices of the division, in Detroit.

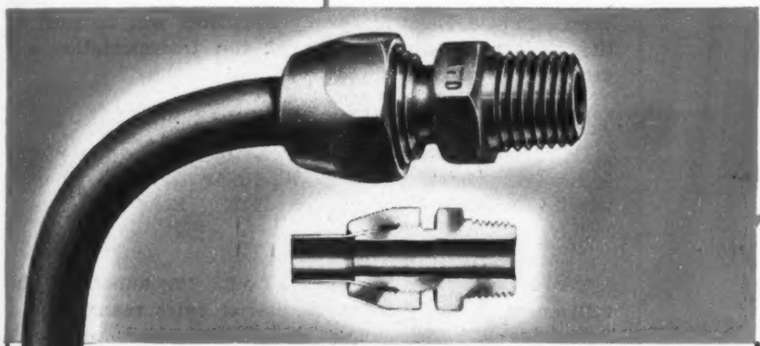
According to a recent announcement John F. D. Rohrbach has been elected president of Raybestos-Manhattan Inc. Mr. Rohrbach succeeds Sumner Simpson, president of the corporation since 1929, who becomes chairman of the board and of the finance committee.

Formerly district sales manager at Birmingham for the Link-Belt Co., C. C. Wiley has been appointed district sales manager at Baltimore, succeeding H. Merrill Bowman. Taking the place of Mr. Wiley in Birmingham is J. T. Bell.

Appointment of George Reed as sales engineer of the Steel and Tube Div. of the Timken Roller Bearing Co. has recently been announced. Mr. Reed will make his headquarters in Houston, Texas.

Assets of the Electronics Division of Illinois Tool Works has been acquired by Lindberg Engineering Co. of 2444





LEAKPROOF JOINTS FOR LIGHT WALL TUBING

- ★ Long, smooth 10° flare provides greater sealing surface. No shearing action; tubing is actually strengthened.
- ★ Only single flare needed for any tubing.
- ★ Up to 2000 flares a day on inexpensive flaring machine.

Superseal FLARED TUBE FITTINGS

Approved by Underwriters' Laboratories for all hazardous gases and liquids.

HAS YOUR DESIGN THINKING shied away from light wall tubing applications when *vibration and high pressure* were present? It needn't if you specify Superseal fittings. The Jaeger Mfg. Co. tested these flared tube fittings exhaustively. One of the tests was on a gasoline engine driven compressor, which was run at full throttle for six hours at 600 p.s.i. They were convinced that Superseal fittings make a leakproof joint unaffected by vibration, perform entirely satisfactorily with welded steel tubing using only a single flare. As a result, Jaeger now standardizes on Superseal fittings for 4 compressor sizes.

Investigate Superseal fittings. Write for new Catalog 4-R, "Grinnell Superseal Flared Tube Fittings".

GRINNELL COMPANY, INC.
Executive Offices: Providence 1, R. I.

Branch Warehouses

Atlanta 2, Ga.	Kansas City 16, Mo.	Philadelphia 34, Pa.
Charlotte 1, N. C.	Long Beach 10, Cal.	Sacramento 14, Cal.
Chicago 9, Ill.	Los Angeles 13, Cal.	St. Louis 10, Mo.
Cleveland 14, O.	Milwaukee 3, Wis.	St. Paul, Minn.
Cranston 7, R. I.	Minneapolis 15, Minn.	San Francisco 7, Cal.
Fresno, Cal.	New York 17, N. Y.	Seattle 1, Wash.
Houston 1, Tex.	Oakland 7, Cal.	

GRINNELL
WHENEVER PIPING IS INVOLVED

W. Hubbard St., Chicago. Manufacture of high-frequency induction and dielectric heating equipment will be continued.

♦

Several new appointments have been made by the sales divisions of the RCA Victor Div. of Radio Corp. of America. These include appointment of P. B. Reed and C. A. LaHar as field sales administrators in the eastern and western divisions, respectively, of the RCA Engineering products department. Mr. Reed will make his headquarters at the RCA offices in Camden, N. J. while Mr. LaHar will have offices at 621 S. Hope St., Los Angeles. Simultaneously, the announcement has been made of the appointment of C. M. Louis as sales manager for Broadcast and Industrial equipment.

♦

Purchase of additional manufacturing facilities near Irwin in western Pennsylvania has been announced by Westinghouse Electric Corp. Facilities will be used by the mica-processing section of the transportation and generator division.

♦

Chicago branch office has been opened by the Cherry Rivet Co. Located at 5707 W. Roosevelt Rd., the office will be under the supervision of Roy Schwab.

♦

Century Electric Co. of St. Louis has announced the retirement of its Cincinnati district sales manager, Leo Schirtzinger. Succeeding Mr. Schirtzinger are P. F. Williams and W. C. Wetlaufer.

♦

Formerly executive vice president and sales manager of the Plomb Tool Co., R. W. Kerr has been elected a vice president and director of the Bingham-Herbrand Corp., Toledo, Ohio.

♦

Manufacturing plant at 2401-2409 Schaefer Rd., Melvindale, Mich. has been purchased by Manco Products Co. Facilities will be used for the production of castings.

♦

Founders of Cleveland Graphite Bronze Co. were recently advanced in position by the board of directors. Ben F. Hopkins, formerly president, became chairman of the board. J. L. Myers, was elected president, taking the position vacated by Mr. Hopkins. C. W. Johnson advanced from vice president in charge of sales to senior vice president and J. J. McIntyre, former senior vice president, became vice chairman of the board.

♦

According to a recent announcement, the apparatus sales department and the arc-welding sales department of the Air Reduction Sales Co. have been merged. The new single department, known as the equipment sales department, will be under the supervision of Dale D. Spoor.

♦

Offices of the Seamless Steel Tube Institute have been moved from their location at 1115 Gulf Bldg., Pittsburgh. New location is 1901 Oliver Bldg., Pittsburgh 22.

♦

With facilities at Sherbrooke, Quebec, Canadian Unitcast-Steel Ltd. has been formed by a combination of United States and Canadian organizations. Parent com-

• ENGINEERED IN PLASTICS BY GENERAL ELECTRIC

Bull's-eye for Plastics

• Plastics score a hit in this unusual application! Stocks for the new Hy-Score target pistols are molded in plastics by General Electric for the Hy-Score Arms Corporation, Brooklyn, N.Y. Called the world's most powerful air pistol, the Hy-Score requires a sturdy stock that will stand up under shock, resist perspiration and grease. G. E. selected a plastics that meets these specifications, then molded the stocks in four distinctive color patterns.

What is *your* plastics problem? Whether you sell pistols or perfume, General Electric's *complete* plastics service may help you lower production costs, improve your product. General Electric, world's largest manufacturer of finished plastics parts, is equipped to design, engineer, and mold plastics products to meet your individual requirements.

Write us for more information. Or get in touch with your nearest G-E Sales Office. We'll be glad to consult with you on any plastics job. Meanwhile, write for your free copy of the illustrated booklet, "Design Data on Plastics." Address: Plastics Division, Chemical Department, General Electric Company, 1 Plastics Avenue, Pittsfield, Mass.

G-E COMPLETE SERVICE—AT NO. 1 PLASTICS AVENUE

Backed by 54 years of experience. We've been designing and manufacturing plastics products since 1894. General Electric research facilities have expanded continually, working to develop new materials, new processes, new applications for plastics parts.

No. 1 Plastics Avenue—complete plastics service—engineering, design, mold-making. G-E industrial designers work with our engineers to create plastics parts, sound and good looking. Skilled mold-makers in G-E toolrooms average over 13 years experience.

All types of plastics. Compression, injection, transfer and cold mold facilities . . . high and low pressure laminating . . . fabricating. G-E Quality Control—a byword in industry, means as many as 160 inspections and analyses for a single plastics part.

GENERAL ELECTRIC

General Electric plastics factories are located in Scranton, Pa., Meriden, Conn., Coshocton, Ohio, Decatur, Ill., Taunton and Pittsfield, Mass.

pany, Unitcast of Toledo, Ohio, formed the new subsidiary in order to manufacture "Wine" railway equipment for Canadian use.

♦

Appointment of F. J. Staroba, formerly sales engineer for Carboloy Co. Inc., to the position of manager of the midwestern district of that company has been announced. Mr. Staroba will have offices in Chicago.

♦

George R. Frankland is the newly appointed Chicago district manager of the Johns-Manville Industrial Products division. Formerly assistant district manager of the Chicago office, Mr. Frankland succeeds Corydon H. Hall who has resigned to become chief executive of a new company being formed in California.

♦

Formerly sales manager of the Engineered Castings Div. of the American Brake Shoe Co., N. George Belbury has recently been appointed vice president.

♦

With headquarters at 1147 S. Independence Blvd., Chicago 24, Hunt-Jordan Co. is now exclusive representative for resistance welding equipment manufactured by Progressive Welder Co. Area covered is northern Illinois including Chicago, and part of Iowa and Indiana. Heading the organization is Donald F. Hunt.

♦

Electrical resistance bulbs formerly handled by the Edison-Splitdorf Corp. are now being manufactured and sold by the instrument division of Thomas A. Edison, Inc., West Orange, New Jersey.

♦

Change of address has been announced by George W. DeBell, plastics consultant. Formerly at 1380 Bedford St., Stamford, Conn., he can now be contacted at P. O. Box 66 East Chatham, New York.

♦

Sterling Injection Molding Inc. has opened an office in the Graybar Bldg., 420 Lexington Ave., New York. They are represented in the area by Gerard E. Quintero Jr. operating from the Graybar Bldg. offices.

♦

Formerly at 60 Woolsey St., Irvington, N. J., Industrial Synthetics Corp. is now located at 225 North Ave., Garwood, N. J.

♦

Associated with the L. H. Gilmer Div. of United States Rubber Co. for the last 35 years, John S. Krauss has recently retired as manager of the division. He will be succeeded by Lawrence K. Youse, assistant manager.

♦

Chronolog Inc., National Bank Building, Detroit 26, has been appointed marketing agents of the National Acme company's Chronolog, a recording instrument. Sales director of Chronolog Inc. is J. E. Thomas, vice president.

♦

Appointment of P. L. Edwards as assistant manager of the central district office in Pittsburgh has been an-

nounced by Raybestos-Manhattan Inc., Manhattan Rubber Div. Mr. Edwards was formerly manager of the company's western division.

♦

With offices at Brightwaters, Long Island, Lauren L. McMaster is now the New York representative of National Formetal Co., manufacturers of bushings and bearings. Mr. McMaster will cover New York, New Jersey and eastern Pennsylvania; he can be contacted at P. O. Box 372, Brightwaters, Long Island, N. Y.

♦

Election of Peter D. White to the presidency of the Babcock & Wilcox Tube Co. was recently announced. Mr. White was formerly a vice president and a director of the company.

♦

Frederick R. Dickerson is the newly appointed sales manager of the Pump Div. of Geo. D. Roper Corp. With the Roper Corp. since 1936, Mr. Dickerson was in the engineering department as well as the pump sales department before being appointed to this new position.

♦

Previously head of special steel sales at the Cleveland plant of Joseph T. Ryerson & Son Inc., W. E. Falberg has been appointed manager of alloy and stainless sales at the company's plant in Chicago. Succeeding Mr. Falberg in Cleveland is E. H. Bodenmann, formerly a sales representative in the stainless steel department of the Ryerson plant in Chicago.

♦

United States Rubber Co. has announced the appointment of Henry A. Rome as manager of molded goods sales to succeed F. W. Archibald, who is retiring.

♦

According to a recent announcement by the Carpenter Steel Co., Omar V. Greene has been promoted from assistant general sales manager to manager of product development. H. Sturgis Potter was promoted from manager of tool-steel sales to sales manager in charge of all Reading products.

♦

Formerly a metallurgical engineer with General Electric Co., Neil F. Ritchey has been named an engineer in the technical service department of the Reynolds Metals Co., Louisville.

♦

Hydraulic Equipment Co. of Cleveland has announced the re-election of Hall Kirkham as president. Continuing in the post of vice president is Harold J. Zimmerman.

♦

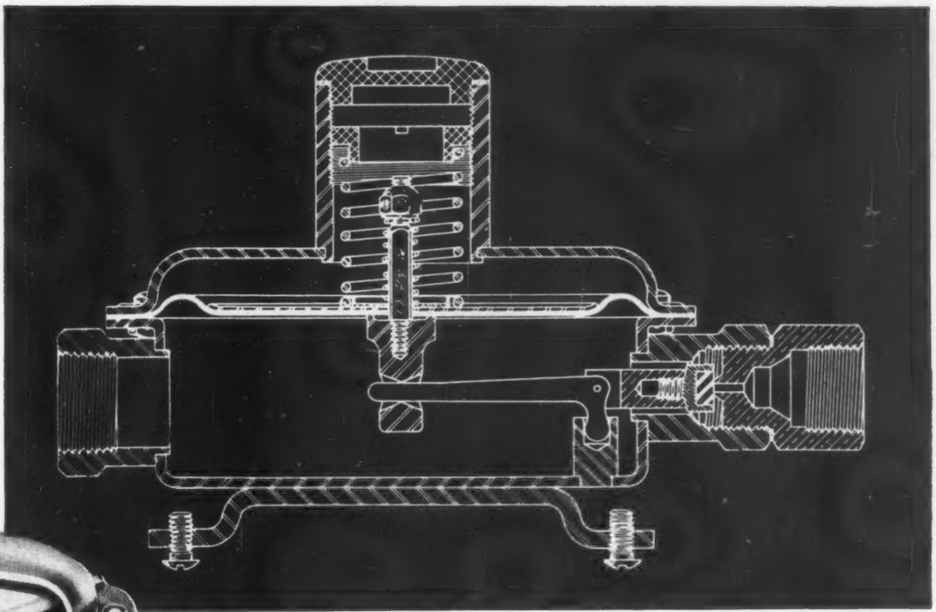
Appointment of Charles B. Miller as district manager of Goodyear Tire and Rubber Co.'s Mechanical Goods Div. at Chicago has been announced. Mr. Miller succeeds G. E. McMahon. He is succeeded in his former post, by W. F. Burdick.

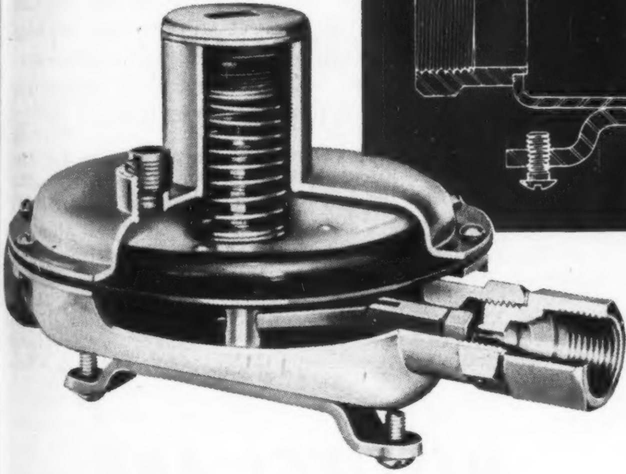
♦

Formerly sales engineer, R. C. Ochs has been appointed sales manager of the Saginaw Dynamatic Devices Div. of Eaton Mfg. Co. Mr. Ochs was formerly with National Acme Co.

♦

Election of W. S. Austin to the post of vice president has been announced by LeMaire Tool & Mfg. Co. Mr. Austin will continue as sales manager of the company.





Nonmetallic Diaphragms

(Concluded from Page 158)

the outlet for an oil cushion to be trapped when the accumulator is discharged in order to minimize stress concentration on the rubber bag wall. The tapered shape of the bag eliminates the trapping of the fluid while it is being discharged by providing progressive expansion of the bag itself toward the discharge end.

The preceding illustrations should give some indication of the variety of conditions which can be successfully handled by the correct application of flexible nonmetallic diaphragms. Contingent upon careful mechanical design and selection of materials there is almost no limit to their versatility.

The author wishes to express his appreciation for the valuable assistance and helpful co-operation given in the preparation of this article by the following companies:

H. Belfield Co. .... Philadelphia
Greer Hydraulics Inc. .... Brooklyn, N. Y.
Grumman Aircraft Engineering Corp. .... Bethpage, Long Island, N. Y.
The New York Air Brake Co., ... Watertown, N. Y.
Weatherhead Co. .... Cleveland
The Federal Welder & Machine Co. .... Warren, Ohio

MEETINGS AND EXPOSITIONS

June 17-19—

American Society of Mechanical Engineers. Applied Mechanics division meeting to be held at the Illinois Institute of Technology, Chicago. C. E. Davies, 29 West 39th St., New York 18, is secretary.

June 21-25—

American Institute of Electrical Engineers. Summer general meeting to be held in Mexico City, Mexico. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18. H. H. Henline is secretary.

June 21-25—

American Society for Testing Materials. Fifty-first annual meeting to be held at the Book-Cadillac Hotel, Detroit. Robert J. Painter, 1916 Race St., Philadelphia 3, is assistant to the secretary.

June 28-July 1—

American Electroplaters' Society. Thirty-fifth annual convention to be held at the Ambassador Hotel, Atlantic City, N. J. Additional information may be obtained from the national offices at 473 York Rd., Jenkintown, Pa.

June 29-30—

National Warm Air Heating and Air Conditioning Association. Mid-year convention to be held at the Edgewater Beach Hotel, Chicago. George Boeddener, 145 Public Square, Cleveland 14, is managing director.

Aug. 10-13—

First Western Packaging Exposition and Conference to be held in the San Francisco Civic Auditorium, San Francisco. Clapp & Poliak, Inc., Empire State Bldg., New York 1, are managing the exposition.

Aug. 18-20—

Society of Automotive Engineers. West Coast meeting to be held at the St. Francis Hotel, San Francisco. John A. C. Warner, 29 West 39th St., New York 18, is general manager.

(Continued from Page 152)

pointer movement in relation to the change in reading. All dials were conventional in that the dial scale increased in the clockwise direction. Of necessity, therefore, an increase in reading was indicated by upward pointer movement at the 9 o'clock position, movement to the right at the 12 o'clock position, and downward movement at the 3 o'clock position. Apparently the direction of movement at the 9 o'clock position has the most natural or logical relationship to the accompanying increase or decrease in reading.

As is readily apparent, direction of movement is an important variable affecting the speed and accuracy of qualitative instrument reading. For quantitative instruments with little or no direct relation to a control motion, the problem is usually solved by following the convention of having the scale increase in the clockwise direction on circular dials, and upward or to the right on linear dials.

Where knobs, cranks, levers or switches control instrument readings, the problem becomes more complex. In aircraft, the convention is normally followed of using clockwise, forward, or upward motion of the control for increase. Situations arise in which the convention cannot be followed, and in all cases it seems most desirable to use the motion relationship which the operator is most likely to try on his first attempt. In studies the following general principles have been shown to apply to reaction preferences:

1. If a rotary control knob moves in the same plane as a linear indicator, the operators consistently respond as if they expect the indicator to move in the same direction as the edge of the knob nearest the indicator
2. When the indicator moves in an arc and moves in the same plane as a knob, the operators respond as if they expect the indicator to rotate in the same angular direction (clockwise or counterclockwise) as the knob
3. If the knob and indicator movements are in different planes, there appear to be no consistent operator preferences.

From these findings we can conclude that wherever possible, rotary knobs and the indicators which they control should move in the same plane of space, and should follow the principles as stated above for linear and circular indicator movements. Much additional research, particularly with other types of controls and indicators, remains to be done on this problem.

Quantitative Reading: In quantitative readings of instruments it is inevitable that two general types of reading error will appear. The first type, which we can call "precision" errors, result from such factors as inaccuracy in interpolating pointer position between graduation marks, parallax, and poor definition of the pointer and markings. The second type we will call "interpretation" errors, since they result from failure to correctly interpret what is seen, with the result that grossly erroneous values may be assigned to the instrument markings.

The so-called "precision" errors are usually too small in magnitude to be a serious hazard in aviation. Reading precision can normally be increased by expansion of the scale or by increasing the number of

graduation marks. Increasing the number of graduation marks, however, has definite limitations as illustrated in *Fig.* 5. The very finely divided 1-unit dial gave only slightly more accurate readings than the 5-unit dial. In an experiment where dials were exposed for a limited time, it was found that finely divided dials actually were read less accurately than the same dials with the small divisions deleted. The explanation appears to be that closely spaced divisions increase the complexity of the dial. The resulting increase in interpretation errors offsets the advantage of small divisions.

Interpolation errors have been investigated in relation to the size of the graduation intervals. *Fig.* 6 shows the magnitude of the intepolation error plotted as a function of the linear distance between scale divisions. It is evident from the curve that very little increase in accuracy of interpolation can be gained by scale divisions greater than 0.25-inch. As the scale divisions are reduced below this value, however, the interpolation error, when expressed as a percentage of the space between marks, increases rapidly. From the point of view of interpolation error, it is concluded that the optimum spacing of dial graduation marks is approximately 0.25-inch.

"Interpretation" errors are a serious problem wherever quantitative data are obtained from instruments. These errors may be very large and are often multiples of 10,000 or 1000 units. In aviation, for example, 1000-foot errors in reading the altimeter are a particularly serious hazard. In Field Artillery, 100-mill errors in readings of micrometer azimuth scales were a serious problem in the recent war. It is quantitative reading errors of this type, where faulty interpretation leads to large and repeated errors, that are in greatest need of investigation.

Quantitative errors in altimeter reading and methods of reducing them have been investigated. Nine experimental indicator designs, including the conventional three-pointer altimeter, were studied. Twelve settings were read on each indicator by 97 USAF pilots and 79 college men without aircrew experience.[7] Results are shown in *Fig.* 7 for the conventional altimeter and for a combination pointer and counter indicator which, from the results of this experiment, has been recommended for future use. Also shown are the results for a direct reading counter.

CONCLUSION: The foregoing provides a survey of some of the psychological research aimed toward improvement in ease of reading of aircraft and other instruments. The results which have been cited illustrate that great improvements in reading ease can be achieved by changes in the manner of displaying the information to the man. It should be emphasized that psychological research in this field is in its infancy, and that a vast amount of additional research is needed. In time, however, we can hope to see the emergence of basic principles which describe the optimum methods of feeding information into the human servo link between instruments and machine controls. By the application of these principles to the design of instruments, it should be possible for engineers to increase human efficiency and safety in many of man's complex tasks.

DESIGN ABSTRACTS

Full Scale Development

COMPLICATED aircraft systems can be developed to the point where their incorporation in an airplane will not result in undue mechanical difficulty. One of the finest examples to back up this statement is the hydraulic system of the Constellation. Lockheed engineers realized that the hydraulic system would be the heart of the airplane because it was being depended upon to operate the flight control surfaces in addition to performing the many functions normally handled by a hydraulic system. They were also well aware of the generally bad reputation of hydraulic systems in contemporary aircraft. It was freely predicted around Wright Field that the Constellation hydraulic system would keep the airplane on the ground most of the time.

Checking Hydraulic System Design

The Lockheed company built an elaborate mock-up of the hydraulic system, which actually was a full-scale working model. This test hydraulic system duplicated the entire system as conceived for the airplane in every detail. The mock-up was equipped with a cockpit, and it was possible to "fly" the mock-up in the research department, operating the flight control system by the hydraulic boost against loads equal to the aerodynamic loads later to be imposed on the surfaces. You could also steer the nose wheel, retract the landing gear, operate the flaps, and operate the automatic pilot, all against loads exactly the same as those which would later be imposed on the system in the actual airplane. This mock-up permitted Lockheed to check numerous conditions which they designated "What-Ifs." Such as, *what if* one hydraulic pump fails? *what if* the line to the inboard flap cylinder ruptures? From the many hours of operation of this system and checking innumerable "what-ifs," much was learned about the hydraulic system and many design changes and modifications were developed and incorporated in the actual airplane. It is gratifying to say the least that the hydraulic system in the Constellation, complicated as it was, caused much less trouble than was expected and far less trouble than much sim-

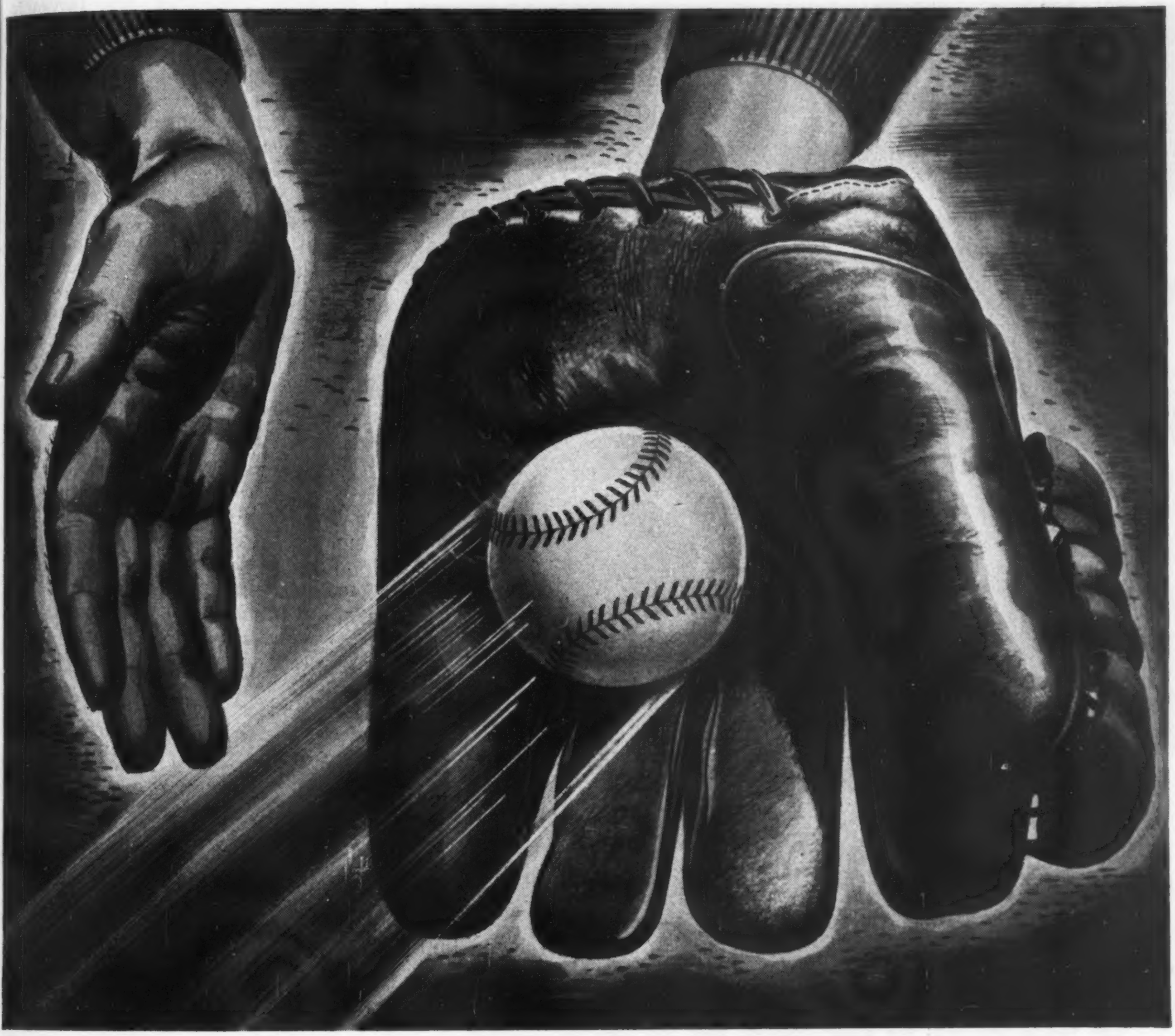
pler hydraulic systems in other airplanes had been causing.

Many people have recommended that the airplane industry should look to the automotive industry for advice and for examples of how a new model should be prototyped, tested, and proved prior to placement into production. It is realized that there is no real basis for comparison of the airplane industry to the passenger car industry. However, there are certain lessons which can be learned from the passenger car industry. One fact which is worthy of note is that practically all of the engineers of a passenger car manufacturing industry are owners and operators of cars. Their designs are, therefore, influenced by their knowledge of actual operating problems and conditions. Aircraft manufacturers certainly cannot hire owners and operators of transport airplanes, but there are methods by which they could take advantage of actual operating knowledge. Several means to attain this end are available. Manufacturers should send their engineering group heads on periodic visits to airline maintenance and overhaul bases. They should also bolster their engineering staffs by requiring that a certain percentage of new engineers hired have airline experience.

We can and should look around us in the aircraft industry for examples of how to develop aircraft systems and airplanes. These observations will be much more beneficial and profitable than endeavoring to investigate methods used by the automotive industry which are beyond the realm of possibility for the aircraft industry. The development of the Constellation hydraulic system is one example of how a complicated system can be tested, improved, and finally developed prior to placement of the airplanes into production or into airline service.—*From a paper by L. R. Koepnick of Transcontinental & Western Air, Inc., presented at the recent SAE national aeronautic and air transport meeting in New York.*

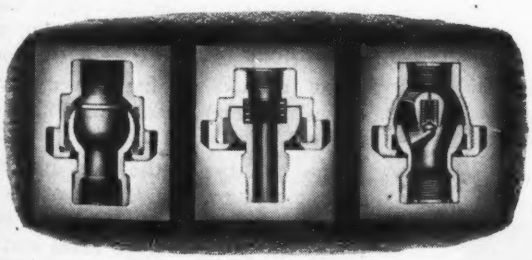
Applications of Silicone Rubbers

SILICONE rubber offers the design engineer a solution to many temperature problems because of its superiority to conventional rubbers under high heat. It retains its flexibility, resiliency and surface hardness over a range of temperature from -70 F to $+500$ F, for long periods of heat aging. In addition, its resistance to oxidation, its low compression set, and its good



TO ABSORB SHOCK

—Fuel Lines need Barco Flexible Joints



The battering impacts and shocks of vibration in mechanical operation are absorbed by Barco Flexible Joints. Providing for expansion and contraction, they keep pipes aligned, protect fluid-conveying systems against interruptions or breakdowns. In every branch of industry and transportation you will find Barco Joints at work, giving fuel line systems longer life, insuring steadier and more economical operation. Full details on request. Barco Manufacturing Company, 1806 Winnemac Avenue, Chicago 40, Illinois.

BARCO FLEXIBLE JOINTS

Not just a swivel joint . . . but a combination of a swivel and ball joint with rotary motion and responsive movement through every angle.

FREE ENTERPRISE—THE CORNERSTONE OF AMERICAN PROSPERITY

In Canada: The Holden Co., Ltd., Montreal, Canada. **"MOVE IN EVERY DIRECTION"**

electrical properties are favorable factors in many applications. Limitations of the material can be largely overcome by proper design.

Since the properties of silicone rubber do not match those of natural or synthetic rubber at room temperature, misconceptions of this material will arise if it is merely substituted for conventional rubber in existing designs. However, design problems are simplified because fabrication of finished parts from the compounded silicone stocks can be accomplished in many ways. Techniques of molding, extrusion, wire coating, laminating, cloth coating and bonding have been worked out successfully.

Gaskets, Seals and Packings

Industrial uses to which the new product may be put are varied. Among these is its use for gaskets and packings. Its flexibility and long life at high temperatures make it especially suitable for gaskets where hot air under pressure is being transferred. In this application, designs proved successful in a 16-cylinder diesel engine where operating conditions were 300 F and 15 psi air pressure. The heat aging of the silicone rubber in this case eliminated frequent replacement of the gasket.

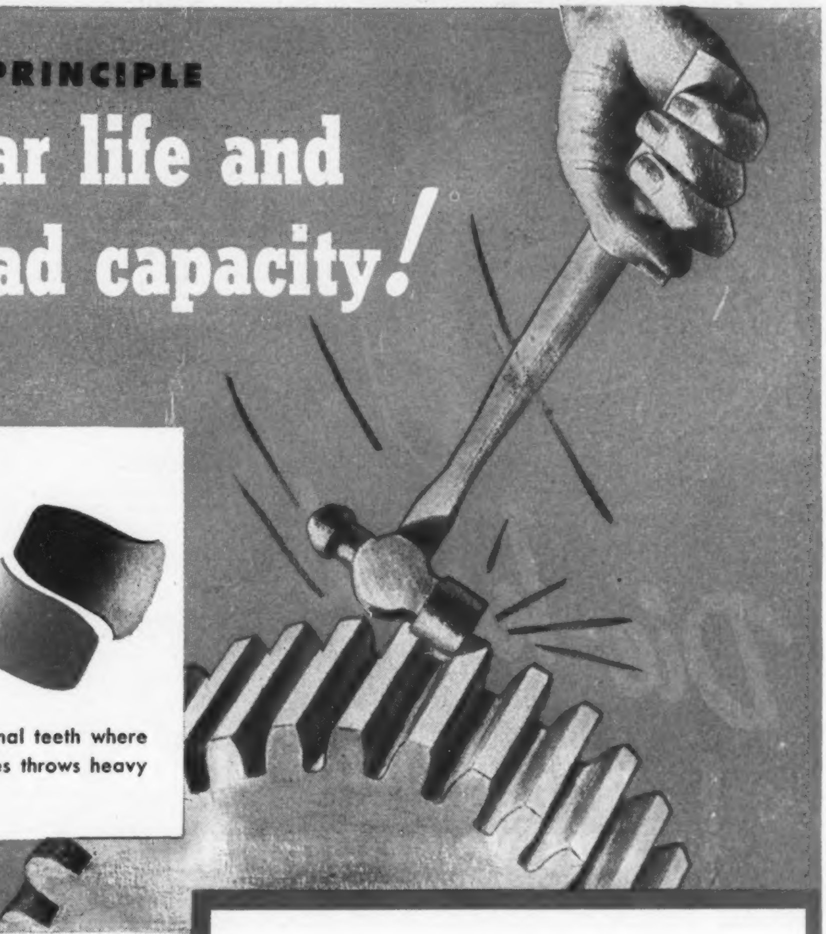
In an early model aircraft turbo supercharger, a large O-ring gasket was necessary for proper sealing action. An extruded silicone rubber rod bonded at the ends to form an O-ring provided successful gasketing action. Operating conditions were 400 F. An O-ring design of silicone rubber provided an effective oil and air vapor seal on the TC-180 jet engine. The temperature at the point of seal was 350 to 400 F. No swelling was observed from the effects of the oil vapor and the gasket could be reused.

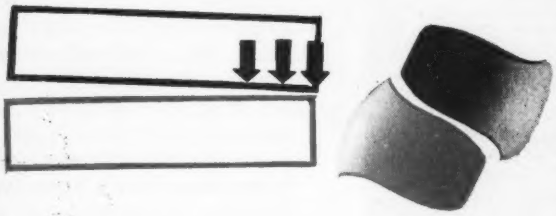
V-rings or chevron packings can be molded from silicone rubber stock to increase the operating temperature of oil seals. A seal was provided around a high-speed shaft where oil temperature was between 300 and 400 F.

One quality of the new material is that it has no tendency to stick or adhere to metallic or nonmetallic surfaces. In the discharge valve seat of an electric hot water heater, high temperatures and no adhesion were the problems. A silicone rubber valve met both requirements.—*From a paper by George S. Irby Jr., Wyman Goss and James J. Pyle of the General Electric plastics laboratory at Pittsfield, Mass., presented at the recent annual meeting of the ASME.*

THIS MECHANICAL PRINCIPLE

Prolongs gear life and increases load capacity!

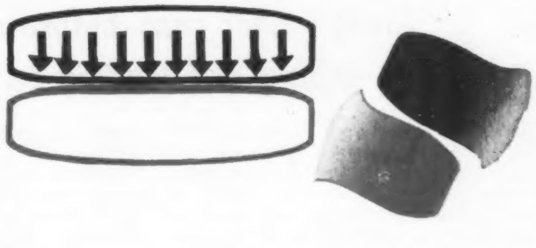




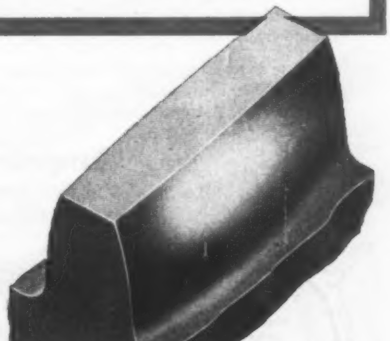
Pitch line section through two conventional teeth where a slight misalignment of the gears' axes throws heavy end bearing on both teeth.

If you wanted to break a gear tooth, you could do it easier by hammering on one end rather than in the center of the tooth.

That is just what gear manufacturers want to avoid, so they prevent dangerous end bearing on gear teeth by shaving them to the Elliptoid form. Then slight misalignments due to deflections and manufacturing tolerances can't put critical loads on the ends of the teeth where they are most vulnerable. In other words, the specified lead tolerance is taken in a curved line rather than a straight one.



Similar section through two Elliptoid teeth. Although bearing extends across 85% of the tooth face, misalignment cannot impose end bearing on either tooth.



The Elliptoid or crowned tooth, exaggerated to illustrate the principle involved. Actual modification is normally less than .0005".

The Elliptoid gear tooth form is produced on Red Ring Rotary Shaving Machines. For further information, write for descriptive bulletin.

2868

NATIONAL BROACH AND MACHINE CO.
5600 ST. JEAN • • • • • • • DETROIT 13, MICHIGAN

NEW MACHINES

And the Companies Behind Them

Commercial

ELECTRIC FAN. Size, 24-in. Three speeds deliver 4800, 3600 and 2100 cfm at 24 inches. Safety feature prevents fan from tipping. Motor, ¼-hp, 6-pole, permanent split-phase induction type, fitted with porous bronze bearings. Dynamically balanced aluminum rotor. G-M Laboratories, Chicago.

AIR CIRCULATOR. Multi-vane blower gives 360-degree diffusion of air. Soft rubber feet cushion vibration. Operates on 110 volts, 50 or 60 cycle a-c; 10 inches high, 7½ inches diam. Electronic Rectifiers, Inc., Indianapolis 2, Ind.

DISH WASHER. 1250 dishes per hour; automatically timed cycles. Hood has two counterbalanced doors. Centrifugal pump, open type, non-clogging, submerged, 150 gals water per minute at 10 lb pressure. Steam injector with thermostat; 1 hp motor. Champion Dish Washer Co., Erie, Pa.

DISH WASHER. 1200 dishes per hour; automatic lift; automatically timed wash and rinse. Tank capacity, 12 gal; ⅓-hp motor; pump, 60 gals per minute at 7-8 lb spray pressure. Gas, electric, or steam heat; safety overflow; 16-gage stainless steel tank. Thermo Cuber Co. Inc., Chicago 14.

Communications

SOUND MOTION PICTURE PROJECTOR. Projects 35-mm pictures directly onto pickup tube of television film camera. Pulsed light source, electronically triggered to provide 60 high-intensity flashes per second, eliminates need for shutter. All moving parts automatically and continuously lubricated. Radio Corp. of America, RCA Victor Div., Camden, N. J.

Domestic

ELECTRIC WALL HEATER. Built-in. Radiant-convection principle; 1320 watts, 115 volts ac-dc; delivers 4507 Btu per hour. Exposed surfaces, hammer-tone gray; reflector, highly polished corrugated aluminum. Two Nichrome wire heating elements. General Electric Co., Bridgeport 2, Conn.

OIL HEATER. Combination oil boiler-burner; automatic; for hot water heating systems. Consists of boiler, burner and five controls. Boiler is cast iron, has low draft loss. Burner is flange-mounted, attached on

three studs. United States Radiator Corp., Detroit.

WRINGER WASHER. Holds ten pounds dry clothes. Wringer rolls stopped by slight-pressure push or pull. Washing done by aluminum-alloy activator. Porcelain-enameled, self-draining tub mounted on rubber gasket. Friction-driven pump empties tub in two minutes. General Electric Co., Bridgeport 2, Conn.

FLATPLATE IRONER. Has no cabinet cover. Ironing surface, 300 square inches; 400 pounds pressure applied hydraulically, handle controlled. Two G-E Calrod heating elements clamped to aluminum shoe. Two thermostats provide individual temperature control at each end of shoe. General Electric Co., Bridgeport 2, Conn.

AUTOMATIC CLOTHES WASHER. Washing done by activator which soaks, flexes and rubs clothes. Waters continuously circulated through filter screens. In seven-minute drying cycle, clothes are spun at 1140 rpm. Antisyphonage system. General Electric Co., Bridgeport 2, Conn.

Industrial

SPRAY MACHINE. Handles up to six tons wet material per hour. Variable speed range to 20,000 rpm; power ratings to 60 hp. Stainless steel feed pipe and atomizing wheel. Shaft assemblies dynamically balanced. Gravity fed oiling system; centrifugal atomization. Bowen Engineering Inc., Garwood, N. J.

POWER UNIT. Hydraulic. Consists of: 35-gal oil storage tank, electric motor, 1000-psi gear pump, relief valve, coupling, pipe and fittings, and suction hose and clamps. Three sizes: 6 gpm, 10 gpm and 15 gpm. Hydro-Power Div., The Hydraulic Press Mfg. Co., Mount Gilead, O.

ELECTRIC GENERATOR. Air powered; portable. Supplies power to operate two 75-watt, 115-volt lamps. Cannot be harmed by short circuits or overloads. Air consumption: 10 cfm at 90 lb pressure. Ingersoll-Rand Co., Phillipsburg, N. J.

DIESEL ELECTRIC PLANTS. Air-cooled (2500-watt) and water-cooled (10,000 to 35,000-watt). Electrically cranked engines; automatically regulated generators; rubber shock mounting; built-in instrument panels. D. W. Onan & Sons, Inc., Minneapolis.

SCALING HAMMER. Pneumatic. For removing rust, scale, paint, soot, etc. Easy-feathering throttle control; self-seating type main valve. Valve mechanism sealed against air leakage and dirt. Master Pneumatic

Tool Co. Inc., Orwell, O.

Manufacturing

RIVETING MACHINE. Pneumatic. Combines hammer action with rotation. Motor consumes 6 cfm air at 25 psi; 4000 to 10,000 short-stroke blows per min. Throat depth, 4¼-in.; anvil height, 40 in.; overall height, 65 in.; weight, 275 lb. Schlack Mfg. Co., Detroit 4.

STAKING MACHINE. Automatic. For staking or riveting fixed or movable joints. Uniform hammer-blow action. Four sizes available, manual or motor driven. High Speed Hammer Co. Inc., Rochester 5, N. Y.

BASEBALL BAT BRANDING MACHINE. 200 bats per hour. Burns trademark on bat or applies color. Electrically heated branding head thermostatically controlled. Floating type cradle rolls with spring pressure; cam action places mark on bat. Powered by ½-hp gearmotor. The Acromark Co., Elizabeth 4, N. J.

SHEET AND STRIP MARKER. Prints all materials of any thickness at up to 2000 feet per min. Powered by rubber-wheeled friction drive. Brass-back dies held by spring pin. Die pressure adjustable. The Pannier Corp., Pittsburgh 12.

UTILITY TOOL. Pneumatic. Variable speeds, 700 to 2400 rpm. High-torque geared motor, operable from 1½-hp compressor. Used for polishing, sanding, drilling, wire brushing, etc. Weight, 2¼ lb. The Aro Equipment Corp., Bryan, O.

ENAMEL APPLIER. Automatically enamels raised faces of letters, numbers or designs on signs, license plates, name plates, etc. Disk revolving beneath enamel fountain transfers enamel to rolls which pass over parts. Feeding by conveyor or hand. Motor, ½-hp, 200-volt, 3-phase, a-c. The Acromark Co., Elizabeth 4, N. J.

VIBRATING HAND TOOL. For marking and etching steel, glass, plastics, etc. 7200 strokes per minute. Plastic case. 110-125 volts, 60-cycle. Weight, 9 oz. Handicraft Division, Burgess Battery Co., Lake Zurich, Ill.

EMBOSSING AND JACKETING PRESS. Draws sheet plastic into cylindrical matched containers and covers. Automatic drawing cycle with electronic timing and dual heat control. Capacity, 4-in. diameter parts. Taber Instrument Corp., North Tonawanda, N. Y.

Materials Handling

FLOOR-TO-FLOOR CONVEYOR. Various models; 3-ply, 28-oz duck ruff-top rubber-covered belt 8 to 24

inches wide. Driven by gearhead motor. Sage Equipment Co., Buffalo 13.

ELECTRIC LIFT TRUCK. Two speeds "dead man" controlled by foot pedal. Full lift, 4 inches. Rubber-tired wheels. Battery, 340 amp-hr capacity. Lifting is by motor-operated hydraulic pump and simple ram. Market Forge Co., Everett 49, Mass.

PORTABLE ELEVATOR. Two capacities, 1000 and 2000 lb. All-welded steel construction. Hand-powered hoist units have automatic holding brake. Heavy-duty, foot-operated floor lock. The Economy Engineering Co., Chicago.

SUSPENDED-FORK TRUCK. Battery powered. Automatic tilt; nonskid drive tire; hydraulic lift. Road clearance, 4⅝-in. Capacity, 2500 lb for 36-in. load. Lifting height, 64 in.; overall height 79 in. Automatic Transportation Co., Chicago.

ELECTRIC FORK TRUCK. Capacity, 1000 lb. Lift range, 83 to 130 inches. "Deadman" type brakes released by depressing brake pedal. Pivot point steering. Only five lubrication points. Lewis-Shepard Products Inc., Watertown 72, Mass.

Metalworking

MULTIPLE-PURPOSE MACHINE TOOL. Drills, reams and chamfers hole and saws slot in both ends of suspension spindle support arms. Work table mounted on ball bearing race with micro adjustment for table clearance. Hydraulic table indexing; drill heads individually counterbalanced, hydraulically operated. Electrical system provides for manual or automatic cycling. The Davis & Thompson Co., Milwaukee.

TUBE DEBURRING MACHINE. Handles tube, pipe and rod to 2 in. diam. Hardened and ground spindle in preloaded, grease-sealed ball bearings. V-belt drive. Positive work stops. Motor, ½-hp; weight of machine, 170 lb. Pines Engineering Co., Aurora, Ill.

STRAIGHTENING PRESS. Hydraulic; 75-ton. Reinforced welded steel construction; motors built in; rams direct acting from hydraulic cylinders in head. Stroke, 12 inches; power stroke speed, 45 in. per min. Colonial Broach Co., Detroit.

HYDRAULIC BROACHING MACHINE. Internal, vertical pull-up type. Capacity, 30 tons; stroke, 60 in. Helix lead and nut bar drives broaches during pull stroke. Pushbutton controls; operating cycles electrically interlocked; equipped with chip conveyor. The American Broach & Machine Co., Ann Arbor, Mich.

HAND MILLER. Variable speeds, 160

to 1460 rpm. Vertical feed, 15¾ inches on knee, 4 inches on spindle head. Spindle mounted in tapered roller bearings. The United States Machine Tool Co., Cincinnati.

SPECIAL MACHINE TOOL. Four finishing operations on automotive cylinder blocks. Single-lever cycle control; hardened and ground steel ways; hydraulic feed, rapid traverse; uses duplicate standard units. Conveyor carries parts to and away from machine. The Cross Co., Detroit.

BACK-GEARED PUNCH PRESS. Capacity, 56 tons. Frame cradle mounted, inclinable to 35 degrees. Ratchet feed operates on thrust ball bearings through square-threaded screw. Foolproof nonrepeat trip mechanism. Bed area, 21 by 30-in.; strokes per minute, 50. Diamond Machine Tool Co., Los Angeles.

TWIN MILLER. Double-spindle, high-precision. Two opposed independent geared milling heads powered by pancake type motors. Each head has fifteen spindle speeds from 55 to 2080 rpm. Each head adjustable in three planes. Table pneumatically powered by solenoid-operated air cylinder; hydraulically controlled cutting stroke. W. H. Nichols Co., Waltham, Mass.

SMALL GEARED PUNCH PRESS. Fourteen-ton, open-back, inclinable. Strokes per minute, 65; stroke length, 2 inches. Nonrepeat, single-trip mechanism. Diamond Machine Tool Co., Los Angeles 23.

Processing

AUTOMATIC CLARIFIER. Removes abrasives, dirt, etc., from water-soluble coolants used in machine tools. Coolant is filtered through wire mesh screens of Monel. Periodically, clean coolant is forced back against filter screens to clean them. Honan-Crane Corp., Lebanon, Ind.

Service Equipment

AIRCRAFT SERVICE TRUCK. Supplies ground power service for airplane engine starting, heating and cooling systems, etc. Equipment includes universal couplers, front and rear, and floodlights which can be detached and extended 50 feet. Motor Generator Corp., Troy, Ohio.

Woodworking

UNIVERSAL WOODWORKING MACHINE. Tooled to groove, rabbet, shape or saw. Fourteen-inch diameter saw driven by 3-hp motor. Ball-bearing roller travel head rides on machined tracks; aligning adjustments for all movements; safety guard combined with adjustable dust spout. DeWalt, Inc., Lancaster, Pa.

940